Technical Reports for Deepwater Horizon Water Column Injury Assessment

WC_TR.10: Evaluation of Baseline Densities for Calculating Direct Injuries of Aquatic Biota During the Deepwater Horizon Oil Spill

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1 Executive Summary

Direct injuries to water column biota may be calculated by combining estimates of water volumes affected by lethal concentrations of oil hydrocarbons with spatially- and time-varying volumetric density estimates for fish and invertebrate species and life stages. Analyses of data from plankton samples, net tows, trawls, and related information were used to develop 2010 baseline abundances, biomass and planktonic density estimates for assessing injuries. National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) stock assessments and NOAA and US Department of the Interior (DOI), Bureau of Ocean Energy Management (BOEM) technical reports were also reviewed and information gleaned was included in the baseline assessment; however, direct injuries were only calculated from the datasets analyzed for fish and invertebrate plankton. Several pieces of information were used to estimate standardized abundances and life stages of the organisms, both from the surveys and the literature, including numbers and biomass caught by sampling gears, length measurements, growth curves, net deployment data, and field information.

The datasets that have been used for the assessment of baseline included:

1. The NMFS Southeast Area Monitoring and Assessment Program (SEAMAP) Ichthyoplankton Survey data from 1999-2009 for ichthyoplankton and small juvenile fish abundance in the upper 200 m in shelf and offshore waters;
2. SEAMAP Invertebrate Zooplankton Survey data from 1999-2009 for invertebrate micro-zooplankton (other than decapods) abundance and biomass in the upper 200 m in shelf and offshore waters;
3. NRDA Plankton bongo sample data from 2011 for decapod larval abundance and biomass in the upper 200m in shelf and offshore waters;
4. NRDA Plankton 1-m^2 MOCNESS sample data from 2011 for fish and decapod larval abundance and biomass below 200m in offshore waters;
5. SEAMAP Shrimp/Groundfish Survey data from 1999-2009 for juvenile and adult fish and invertebrate biomass in shelf waters (depths of 0 – 200 m);
6. NRDA 10-m^2 MOCNESS sample data from 2011 for micro-nektonic pelagic fish abundance and planktonic invertebrate biomass in offshore waters (depths of greater than 200 m);
7. NRDA Pisces Midwater Trawl data from 2011 for nektonic pelagic fish and invertebrate biomass in offshore waters (depths of greater than 200 m);
8. Deep Gulf of Mexico Benthos (DGoMB) Survey data (Powell et al. 2003; Rowe and Kennicutt II 2009) for demersal fish and invertebrate megafauna biomass in offshore waters (depths of greater than 200 m);
9. NRDA Flying Fish Observations from 2011 for juvenile and adult fish abundance in surface waters of shelf and offshore waters;
10. Stock Assessment-based abundance and biomass estimates for juvenile and adult fish in shelf and offshore waters;
11. Nearshore fish and invertebrate biomass (Brown et al. 2013) applicable to estuarine waters inside the barrier islands; and
12. Nearshore (estuarine) larval fish and planktonic invertebrate densities applicable to waters inside the barrier islands (Dauphin Island Sea Laboratory's Fisheries Oceanography of Coastal Alabama (FOCAL) program; Dauphin Island Sea Lab 2009).

As mentioned above, direct injuries were only quantified for ichthyoplankton and invertebrate zooplankton. The datasets with plankton used for the injury quantification included: SEAMAP

Ichthyoplankton Survey, SEAMAP Invertebrate Zooplankton Survey, NRDA Plankton Bongo Survey, NRDA Plankton 1-m^2 MOCNESS, NRDA 10-m^2 MOCNESS, and the FOCAL Program data (Appendix E). The other datasets listed above provided baseline estimates for fish and invertebrate nekton of various life stages in the Gulf of Mexico and are described in this report, but were not incorporated into the injury assessment.

For the SEAMAP Ichthyoplankton Survey data, statistical techniques were applied to predict vertically-integrated larval abundance as a result of spatially- and temporally-varying environmental characteristics. Predicted abundance maps (Christman and Keller 2015) were used to model baseline densities present during the spill from April to August 2010.

Several plankton and nekton datasets from the NRDA sampling program (i.e., items 3, 4, 6, 7 and 9 from above) were incorporated into our assessment of baseline densities. While these samples were taken after the spill, they were used to calculate biomass and, for items 3, 4 and 6 from above, injury for specific organisms and life stages since no other datasets contained quantitative information. The abundances calculated from the NRDA surveys were considered to be a minimum baseline of the pre-spill environment.

Each dataset analyzed for baseline abundance represented different communities of fish and invertebrates by season and sampling location. Within the SEAMAP Ichthyoplankton dataset, fish eggs were the taxonomic group found in the greatest abundance both on and off the shelf in both the spring and summer. Mesopelagic fish (lanternfish, bristlemouths, and hatchetfish) were commonly abundant species in the plankton surveys, as well as the deeper sampling programs targeting nekton (e.g., NRDA Pisces, NRDA 10-m^2 MOCNESS). Within the assessment region, some SEAMAP Ichthyoplankton taxa had predicted abundances (from GAMs) varying in space and time, while other taxa had homogenous abundances within the region from both the arithmetic mean and the GAM predictions. Shrimp trawl sampling comprised many juvenile to age 2 fish (e.g., spot, butterfish, red snapper) as well as commercially significant invertebrates (e.g., brown shrimp, blue crabs).

While this assessment of baseline densities covers a wide range of marine and estuarine fish and invertebrate organisms at varying life stages, data for some groups remain incomplete due to sampling limitations. For example, fast-swimming pelagic species are never or infrequently caught in trawls and other sampling gears. Also, the majority of the data sources used to derive abundance estimates have only sampled smaller fish, typically in the age 0 and 1 year classes. Thus, the abundance and biomass estimates developed herein should be considered minimal estimates for water column biota in the Gulf of Mexico environments affected by the spill.

2 Introduction and Objectives

The objectives of this report are to:

- Review available data that may be used to evaluate baseline abundance and biomass, as well as describe species groups and stages or size classes where quantitative data are lacking;
- Describe the assessment region in the northern Gulf of Mexico used to calculate baseline abundances and biomass;
- Describe rationale for selection of biological datasets used to develop baseline abundance/biomass;
- Describe the development of baseline abundances and biomass for fish and invertebrates in the assessment region by life stage and size class;
- Characterize the sizes of organisms found in the samples used to develop the baseline abundances and biomass; and
- Estimate volumetric densities from the baseline abundances of plankton, for use in injury quantification.

Section 3 provides an overview of the approach to development of biological abundances and biomass, and describes the basis of the assessment region used. Section 4 and Appendix A contain a review of historical biological datasets available from state and federal agencies and academic institutions that could be used to derive baseline estimates for fish and invertebrates in nearshore, shelf and offshore waters. Section 5 provides an overview of the NRDA-collected biological surveys for plankton, juvenile and adult fish, and invertebrates. Section 6 describes the rationale for selecting the datasets, as well as the model for expected and uncertainty ranges applied to estimate biomass and numbers of fish and invertebrates. Section 7 outlines the data sources and the associated processing of the datasets that were used to calculate abundances and biomass. Section 8 provides a brief discussion of the results of the analysis of baseline abundances and biomass and size frequency distributions. Section 9 describes the volumetric density estimates made for plankton.

3 Water Column Injury Assessment Region

The assessment region for the analysis of baseline was determined based on observations of the floating oil distribution, shoreline oiling, sensor measurements, and water column chemistry. The objective was to develop baseline data specific to the areas where most acute toxicity occurred. The assessment region used for analysis of abundance, biomass and densities of water column biota was within the geographic range of 27-31ºN and 87-92ºW (Figure 3-1).

Three "ecozones" were defined geographically in the region: offshore (oceanic) waters >200-m deep, shelf waters <200-m deep but seaward of the along-shore barrier islands (inshore), and estuarine (nearshore) waters inside the barrier islands. In this report, "nearshore" is defined as estuarine waters inside the barrier islands, which are typically <7-m deep, whereas "shelf" or "inshore" refers to waters outside the barrier islands where waters are for the most part >7-m deep. Unique baseline estimates were quantified as averages for each ecozone. While biological distributions are known to be highly variable in time and space, data are not sufficient for all species and life stages to characterize these distributions and patchiness.

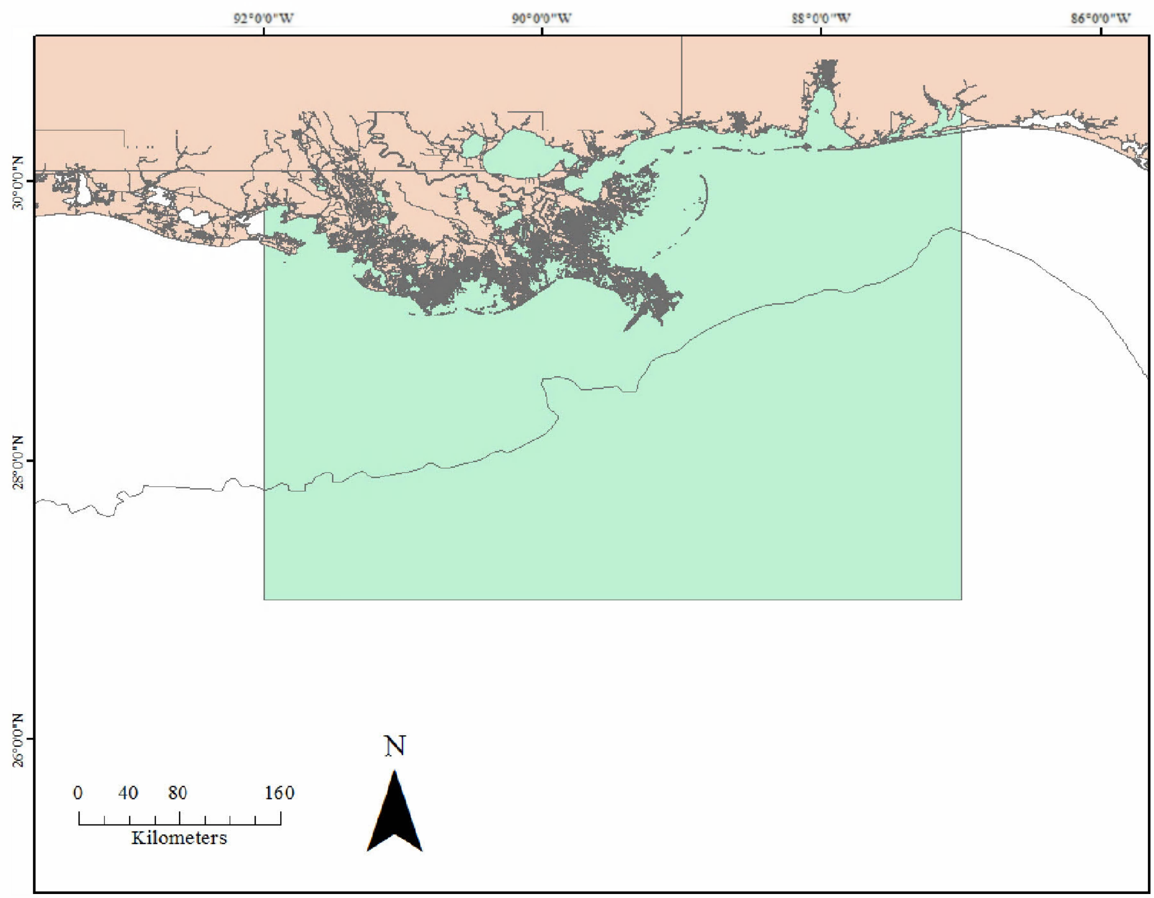

Figure 3-1. The assessment region used for analysis of abundance, biomass and densities of water column biota. Line intersecting the box is the 200-m bathymetry contour.

4 Review of Biological Datasets Available for Developing Baseline Abundance and Biomass

4.1 Biological Sampling of Fish and Invertebrates in Shelf and Nearshore Waters

This section provides a summary of existing data characterizing the abundance and biomass of fish and invertebrates in shelf and nearshore waters (depths <200 m). One of the main datasets used to derive fish and invertebrate density estimates was the National Marine Fisheries Service (NMFS) Southeast Area Monitoring and Assessment Program (SEAMAP). These surveys have been conducted within the U.S. Exclusive Zone (EEZ) and state territorial waters since 1982. The overall objectives of the SEAMAP survey have been to assess the distribution and abundance of recreational and commercial organisms collected by plankton, trap/video, bottom longlines, hook and line, and trawl gears, and then to document environmental factors that might affect the organisms' distribution and abundance (Rester 2009). With 25 years of data, this program offers a significant resource for understanding the characteristics of the natural state of this community.

4.1.1 Plankton

Table A-1 in Appendix A provides a summary of the available datasets for planktonic fish and invertebrates in the northern Gulf of Mexico. Figures A-1 through A-13 of Appendix A summarize the sampling locations for datasets available for plankton fish and crustaceans.

SEAMAP samples are augmented by several state-based surveys that sample in waters closer to shore (Table A-1). In 2009, the SEAMAP program completed a winter, spring, and fall plankton survey. Each of these surveys took over a month to complete. The spring and fall surveys collect samples using bongo and neuston net procedures. The strength of this dataset is its longevity, with 2009 being the 28th year of the program (Rester 2009). The winter survey targets fishes that are underrepresented by the spring/fall sampling procedures and attempts to capture the presence of winter-spawning species. The main limitation of the SEAMAP plankton surveys is that only the spring survey covers the offshore area. To increase temporal coverage, plankton in the inshore (shelf) waters are also collected during the SEAMAP Shrimp/Groundfish survey over several seasons.

SEAMAP sampling was conducted in 2010 during and following the DWH spill; and additional sampling using the SEAMAP methods was completed in conjunction with other sampling for the DWH incident site. As is discussed further in Section 5 of this report, other sampling methods (e.g., image analysis systems such as SIPPER, DAVPR/VPR and ISIIS, see Section 5.1.4) were used to document plankton as well, including in close proximity to the DWH incident site where the presence of oil precluded the use of small mesh nets.

The Dauphin Island Sea Laboratory's Fisheries Oceanography of Coastal Alabama (FOCAL) program (Dauphin Island Sea Lab 2009) consists of a cross-shelf survey that originates within Mobile Bay and employs a version of the BIONESS (Bedford Institute of Oceanography, Net Environmental Sampling System) system called a "Mininess" for sampling. Oblique samples taken over the water column from 2007-2009 using 333 μm mesh nets have been analyzed and ichthyoplankton and small zooplankton have been enumerated.

After reviewing available data and literature describing estuarine plankton (see Appendix A), the FOCAL dataset was chosen to estimate densities for nearshore fish and invertebrate plankton. The FOCAL dataset provided the most recent assessment for baseline plankton densities (2007-2009), and contained the highest number of samples, providing the best estimate of the temporal variability in plankton densities. The FOCAL dataset also had true embayment samples to estimate nearshore densities, while the other available sources' samples were all on the inshore shelf.

4.1.2 Juvenile and Adult Fish and Invertebrates

The SEAMAP program has a long-term summer and fall Shrimp/Groundfish Trawl survey that covers the shelf waters in the area of the DWH spill (Appendix A, Table A-2, Figures A-3, A-7 and A-14). This is augmented by a number of other surveys conducted by NMFS in shelf waters, such as the Small Pelagics survey, Reef Fish Video effort, and Longline surveys (Table A-2, Figures A-15 through A-17). These efforts have been occurring over at least the last decade, and are still on-going.

In addition to NMFS surveys that sample fish and invertebrates within Gulf of Mexico (GOM) shelf waters, there are a number of historic and on-going state- and academic-based surveys. These include surveys conducted by the Louisiana Department of Wildlife and Fisheries (LDWF) Marine Fisheries (Figure A-18), Louisiana State University (Figure A-19), the Alabama Department of Conservation and Natural Resources (ALDCNR MRD), the Florida Fish and Wildlife Research Institute (FWRI), and University of West Florida (Figure A-20). Table A-2 in Appendix A provides more detail on the geographic range and sampling gear used for each of these surveys for juvenile and adult fish and invertebrates.

4.1.3 Biological Sampling of Fish and Invertebrates in Offshore Waters

Abundance and biomass data for juvenile/adult fish and invertebrates that existed prior to the DWH spill for offshore epi- and mesopelagic waters over the shelf break and slope (beyond the 200-m bathymetric contour) in the northeastern GOM are quite limited. NMFS has conducted both surface and bottom long-line surveys that quantify catch per unit effort of several sharks and other highly migratory species (HMS), but only a few of their sampling stations are located beyond the 200-m contour (Appendix A, Figure A-15). The NMFS small pelagics deepwater bottom trawl dataset has a few stations located in deeper waters (greater than 500 m); however, similar to the long-line surveys, the majority of the sampling stations associated with this dataset are located on the shelf (in depths less than 200 m, Figure A-16). The deeper water stations that have been sampled as part of the NMFS small pelagics deepwater bottom trawl survey are clustered south of the Florida panhandle approximately 0-50 nm past the 200-m contour (approximately 150-200 nm east of the DWH spill site). Abundance and size frequency data (from the years 2002-2004 and from 2006 to present) on groundfish and smaller pelagic species can be acquired from these deeper trawl stations (200-500 m). In addition, NMFS has conducted some mid-water trawls in the deeper portions of the mid-GOM during the 2000's. These trawls were primarily focused on attaining data on sperm whale forage base (i.e., squid) in the mesopelagic zone; however, other fish species that were captured were also saved and preserved.

The Gulf SERPANT project is funded jointly by the Minerals Management Service (MMS within DOI; now BOEM and Bureau of Safety and Environmental Enforcement, BSEE), BP, and additional industrial (e.g., Statoil, Total) partners. The project is in part carried out by LSU (Principal Investigator, Dr. Mark Benfield, Louisiana State University). This ROV-based survey of the meso- and bathypelagic habitats (in waters greater than 200 m) has been conducted since 2006 at various deep sea oil platforms in the northern GOM, including the DWH platform. Typically the surveys consist of depth-discrete horizontal video transects of pelagic biota using the industry ROV on the rig that carries out riser pipe inspections. Common species observed include ctenophores, jellyfish, chaetognaths, pyrosomes, decapods, and mid-water fish such as viperfish. Data products of this survey include presence/absence of species, typical biodiversity measures of these habitats, and estimated relative density (based on an approximate volume surveyed). Prior to the spill, this was the most comprehensive dataset for the mid- to deep-water habitats in the offshore region.

Deep sea benthic datasets that exist for the northern GOM include a series of trawls carried out by Gulf Coast Research Laboratory (GCRL) and Florida Department of Natural Resources (FDNR) during the 1980's at depths of up to 900 m. MMS conducted a study of the biological communities that exist around known deep-sea ship wrecks in the Mississippi Canyon (Figure A-21). Counts of benthic fish and invertebrate were carried out at each site. From 2008 to 2009, three cruises to deep water *Lophelia* coral sites and other hard bottom areas were carried out (Figure A-22). ROV sampling for video and mosaic imaging was conducted. Presence/absence and species identification of fish and mobile invertebrates associated with these habitats was recorded. These benthic surveys contain mostly qualitative information on fish and invertebrates.

MMS conducted the Deep Gulf of Mexico Benthos (DGoMB) Study, which was the most comprehensive dataset containing quantitative measure of abundance for deep-sea fish and invertebrates available for use in this assessment. Sampling was carried out using a 40' otter trawl with 2.5" stretch mesh. Sampling depths ranged from 200 m to 3,750 m. The bulk of the fish data was collected during cruises in 2000. Study data includes abundance, species richness, and species diversity information for demersal fishes and bivalves (Figure A-23).

5 NRDA Collected Survey Data

During the pre-assessment phase of the DWH NRDA, the Water Column Technical Working Group (TWG) identified several data gaps in the biological datasets of the Gulf of Mexico (GOM). In order to address these data gaps, approximately thirty cooperative work plans were designed. These plans were primarily developed to collect biological abundance and distribution data for plankton and/or small pelagic fish and invertebrates. These samples require sorting and identification, with about 20 labs having processed the samples. Data are being compiled, evaluated for quality assurance and quality control, and distributed among parties involved with the NRDA and the public. Some of these data (i.e., those available as of October 2014 when the assessment of injury quantification began) were analyzed and integrated into the biological distribution and baseline datasets described herein. This section describes the field sampling programs that were conducted in an effort to provide data to fill the information gaps. Figure 5-1 provides a map of the design for the biological sampling survey stations for bongo/neuston, 1-m^2 and 10-m^2 MOCNESS and midwater trawls.

We used data from several NRDA program surveys, as they were available by October 2014, to develop baseline estimates by gear and taxon. Some of these datasets are comparable to the historical datasets, while others provide the first instances of data of its kind. Thus, given the timeline of analyses and similarities across datasets, several programs' data listed within this section were not analyzed as part of the injury quantification assessment. These data are included in this report solely to describe the various water column biota data collected as part of the NRDA. However, note that data from several NRDA program surveys (i.e., NRDA bongo, NRDA 1-m^2 and 10-m^2 MOCNESS) were used to derive densities for the injury quantification assessment.

Due to the extensive sampling effort in 2011 and the time it takes to process these samples in labs, only a portion of NRDA dataset information was available when we finalized the datasets described in Section 7. For instance, only initial results from the midwater trawl data and the first round of laboratory data from the 10-m^2 MOCNESS samples were used for those datasets. Available plankton data (ichthyoplankton and decapods) were also incorporated into baseline density calculations. Data for other invertebrate plankton, quantified by Zooscan, were not used, as results for only 12 deep (200 m or near bottom) bongo samples were fully processed and released as of October 2014. The SIPPER data were also not incorporated into our datasets because the SEAMAP Invertebrate Zooplankton dataset 1) covers many of the taxa also found in the SIPPER; 2) has more samples for analysis, and 3) is a true baseline dataset (whereas the SIPPER sampling was all conducted post-spill). Data from the imaging systems are expected to be delivered on a staggered schedule with some of the DAVPR data potentially available during the latter part of 2015 and the ISIIS data likely not being produced until the end of 2015.

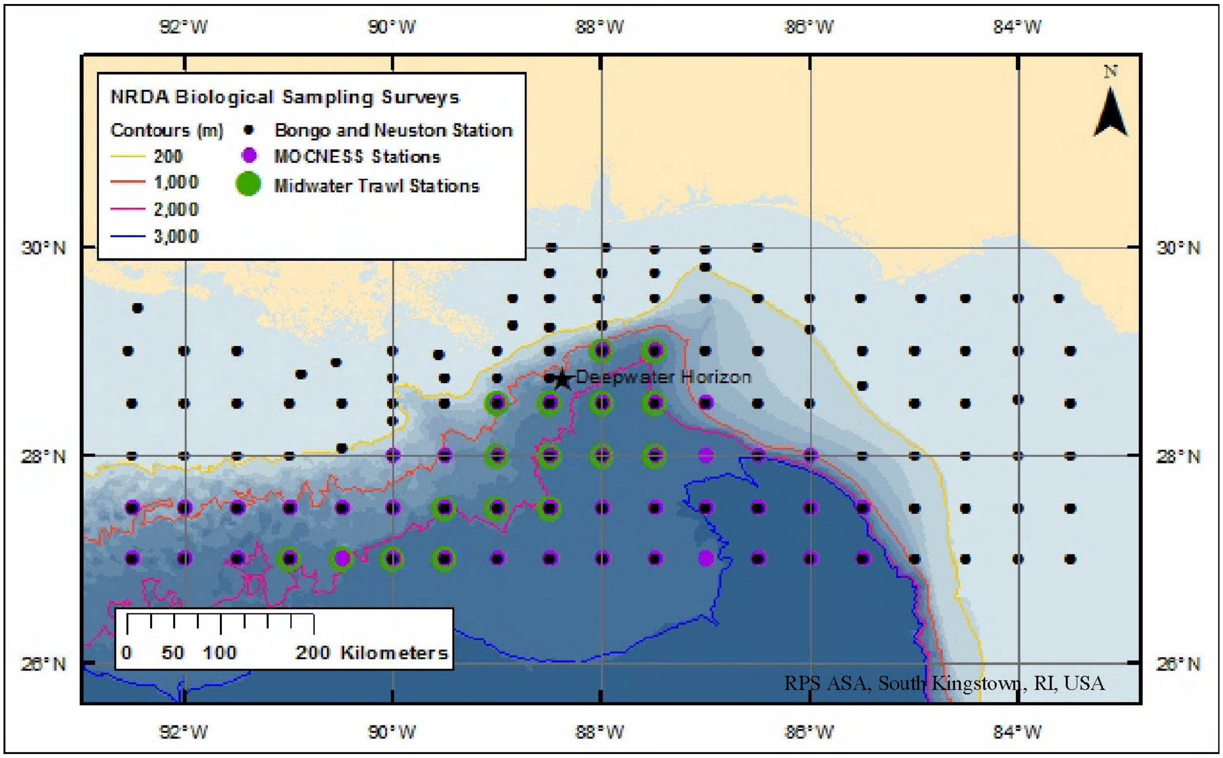

Figure 5-1. Design of NRDA biological sampling survey stations – primary sampling methods: bongo/neuston (black dots), both 1-m^2 and 10-m^2 MOCNESS (purple dots), and midwater trawls (green dots).

5.1 Plankton

NOAA NMFS has been conducting plankton surveys in the GOM for several decades through the SEAMAP surveys. This historical dataset is one of the best examples of long-term monitoring of plankton in U.S. waters. However, the SEAMAP plankton survey targets ecologically and economically important fishes. For NRDA, the focus needed to include all species, both ichthyoplankton and zooplankton, that live throughout the water column, in the epipelagic zone and the deeper water. As such, the NRDA plankton program was designed to augment the SEAMAP program to allow for as much data continuity across the datasets as possible while providing the needed additional information.

Plankton processing under the NRDA program included:

- Identification, size measurements and counting of ichthyoplankton following SEAMAP protocols used for historical datasets,
- Identification, size measurements and counting of decapods using a lowest-identifiable taxon (by decapod taxonomists) strategy, which is at a much lower taxonomic level than that used for historical SEAMAP zooplankton analysis, and
- ZooScan image analysis of other zooplankton.

See the plankton processing work plans (e.g., French McCay et al. 2011a, c; French McCay et al. 2012) and related documentation developed by the NRDA plankton program for details.

5.1.1 Bongo and Neuston

The NRDA bongo and neuston survey sampling stations were primarily those that are routinely sampled by the SEAMAP survey, with the addition of a few nearshore stations (Figure 5-1, black dots). The main objectives for the NRDA surveys were to increase the seasonal sampling and collect pairs of day and night samples at individual stations. SEAMAP plankton surveys are commonly performed in spring and fall. The NRDA survey also included a winter and summer sampling effort. Additionally, the NRDA survey employed a second type of neuston net: a manta net. This net, used extensively by NOAA NMFS for their west coast surveys, is able to more quantitatively sample surface waters than the traditional rectangular net that has been used historically in the GOM.

The NRDA bongo and neuston sampling events included cruises in September-October 2010 (Entrix Plankton Cruises 3 and 4), February-March 2011 (NRDA/SEAMAP *Oregon II* Winter 2011), April-June 2011 (*Bunny Bordelon* Spring 2011), July 2011 (*McArthur II*), and July-September 2011 (*Bunny Bordelon* Summer 2011). The sampling scheme for each cruise can be found in the individual cruise plans; the predominant scheme was to deploy the bongo nets twice (once to 200 m or near-bottom, once to the approximate mixed-layer depth), the rectangular neuston net for duplicate 10 minute tows, and the manta net for duplicate 10 minute tows. Each station was sampled once during the day and once at night. In addition, some bongos were deployed from 0-40 m to sample the upper mixed layer.

5.1.2 1-Meter^2 MOCNESS

The NRDA 1-m^2 MOCNESS (Multiple Opening and Closing Net and Environmental Sensing System) surveys sampled from a set of 45 offshore SEAMAP stations (Figure 5-1, purple dots). This survey was designed to sample at SEAMAP survey stations but increase the frequency (i.e., sample in more seasons and sample both day and night at a single station), increase the spatial coverage (i.e., sample at more stations in the assessment region), and sample throughout the entire water column. While SEAMAP conducts 1-m^2 MOCNESS sampling to a depth of 160 m at select stations on their Plankton Surveys, the NRDA survey was designed to sample to full ocean depth (or to 1,500 m). The lowest depth bin was modified at each station based on local depth, but the remaining bins were standard throughout the NRDA survey.

The NRDA 1-m^2 MOCNESS sampling events included cruises in September-October 2010 (*Walton Smith* 1 and 3, Entrix Plankton Cruises 3 and 4), January-March 2011 (*Nick Skansi* Winter 2011), April 2011 (*Walton Smith* 4), April-June 2011 (*Nick Skansi* Spring 2011), July 2011 (*McArthur II*), and July-September 2011 (*Nick Skansi* Summer 2011). The sampling scheme for each cruise can be found in the individual cruise plans; the predominant scheme was to deploy the MOCNESS to full ocean depth or 1,500 m (whichever was shallower) and retrieve it collecting samples over prescribed depth bins. On the spring and summer 2011 surveys aboard the *Nick Skansi*, the crew also collected SEAMAP-analogous samples by deploying the MOCNESS a second time according to the SEAMAP protocol (maximum depth of 160 m). Each station was sampled once during the day and once at night.

5.1.3 *Sargassum* Community Sampling

Fauna associated with floating *Sargassum* sp. were sampled to determine the consequence of potential habitat loss via oil degrading the floating patches. Fish and invertebrates utilize the *Sargassum* mats for shelter, food, and transport. Ichthyoplankton and larval decapods were sampled using bongo and neuston nets, with tows being conducted through, around, and underneath the *Sargassum* patches. Video footage was also used to assess potential juvenile populations associated with *Sargassum*.

5.1.4 Plankton Image Processing Systems

To further detail aspects of the plankton community, *in situ* plankton imaging systems were deployed as part of the NRDA plankton sampling program. These systems were deployed to help answer questions that are not well resolved using traditional net sampling; including fine-scale vertical distributions, species associations, and fine-scale horizontal changes in density of the plankton community. The datasets described in this section were not used in the quantification of injury calculations for a number of reasons, such as not being available at time of assessment; having a relatively small sample size, and the fact that other datasets used better quantified abundances for imaging targeted life stages.

5.1.4.1 **SIPPER**

The Shadowed Image Particle Profiling and Evaluation Recorder (SIPPER) is an *in situ* suspended particle imaging system. The SIPPER (Samson et al. 2001) and other imaging systems have been demonstrated to provide similar abundance estimates for robust and hard bodied organisms and more accurate assessments of gelatinous organisms as compared with plankton net sampling systems (Remsen et al. 2004). The SIPPER is commonly deployed in a tow-yo pattern (towed obliquely in an up and down pattern) from near the surface to a maximum depth of 350 m. SIPPER was deployed on three NRDA sampling efforts between 4 May and 17 September 2010: *Gordon Gunter, Weatherbird*, and *Specialty Diver*.

During the May-June 2010 *Weatherbird* and *Gordon Gunter* surveys, SIPPER imaged the water in close proximity to the wellhead. This is one of the only plankton datasets from the area of the spill at the time oil was being released. Though the well had stopped releasing oil by the time the *Specialty Diver* survey occurred, September 2010, the May-June 2010 sampling locations were resampled in addition to other locations.

5.1.4.2 **DAVPR/VPRII**

The Video Plankton Recorder (VPR) is the original electronic optical plankton imaging system, developed at Woods Hole Oceanographic Institute by Cabell Davis and Scott Gallager (Davis et al. 1992a, b). The VPR and its subsequent incarnations have been used worldwide to obtain plankton abundance and biomass patterns in relation to hydrographic properties[1]. The DAVPR (digital-automatic Video Plankton Recorder) was designed to have an undisturbed imaged volume, thus minimizing avoidance (escape behavior) of the sampler by zooplankton. The DAVPR is tow-yoed slowly (2-4 knots) by paying in/out wire from a winch, raising and lowering the instrument to depths up to 1,200 m at a rate of 1 m/s. The DAVPR was deployed on three surveys, September 2010 (*Walton Smith* 2), January 2011 (*Arctic* 6), and April 2011 (*Walton Smith* 4) at select locations around the DWH spill location and the northeastern GOM.

The VPRII (Davis et al. 2005) is a high-resolution, *in situ* digital imaging system mounted on a fast (10-12 knot) towfish (i.e., towed apparatus holding instruments) that undulates automatically to depths of up to 300 m and steers to starboard when surfacing to avoid the wake. The VPRII was carefully designed to avoid disturbing the imaged volume prior to sampling it. The single NRDA survey using the VPRII was a GOM-wide survey that imaged the plankton of shelf waters (to ~300 m) from Tampa, FL to Galveston, TX during March-April 2011 (*Oceanus*).

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[1] See list of VPR publications at: ftp://ftp.whoi.edu/pub/users/cdavis/vprpapers/vpr_papers_lista.pdf

5.1.4.3 **ISIIS**

The *in situ* ichthyoplankton imaging system (ISIIS) produces high resolution images of organisms ranging in size from 1 mm (large zooplankton such as copepods) to greater than 10 cm (gelatinous plankton such as salps and ctenophores, as well as small fish; Cowen and Guigand 2008). The ISIIS was designed to sample a large volume of water to allow for the enumeration of low abundance and rare species. ISIIS was deployed in a tow-yo pattern to a maximum depth of 200 m on a survey during June-August 2011 (*McArthur II*). In addition to cross-shelf sampling transects similar to those conducted by both SIPPER and DAVPR, the ISIIS survey also included concurrent net sampling with a 1-m^2 MOCNESS.

5.1.4.4 **ZooScan**

The ZooScan analysis classifies and enumerates small invertebrate zooplankton via an imaging identification system. Unlike the other imaging systems, which perform imaging *in situ*, the ZooScan analyses are performed in the laboratory using net-collected samples. ZooScan processing was performed on plankton net samples from bongo, neuston, manta and 1-m^2 MOCNESS nets.

5.2 Juvenile and Adult Fish and Invertebrates

Historical datasets on juvenile and adult fishes are much smaller and more sporadic than those for plankton. In the GOM, the SEAMAP Shrimp/Groundfish bottom trawl surveys offer some quantitative data on these larger size classes on the shelf and the continental slope but do not cover the deeper waters. The NRDA surveys targeting these size and age classes focused on collecting data from the deeper offshore waters.

5.2.1 Mid-water Trawl Sampling

In order to assess the nekton community in the deeper waters of the offshore environment, NRDA conducted a series of four cruises utilizing midwater trawl gear (*Pisces 8* in December 2010, *Pisces 9* in March-April 2011, *Pisces 10* in June-July 2011, and *Pisces 12* in September 2011). This survey targeted sixteen offshore SEAMAP stations within the vicinity of the DWH wellhead and to the south and west in offshore waters (Figure 5-1, green dots). Figure 5-2 depicts the stations actually sampled during the four cruises. The main goal was to evaluate the nekton community above and below 700 m water depth. The sampling methods included paired trawl (using an Irish Herring Trawl, IHT) deployments, one to 700 m and one to full station depth or 1,400 m, whichever was shallower. Each station was sampled both during the day and at night. By sampling throughout the year, the data should also be able to address any seasonal changes in this community. More information can be found in the cruise plans for each survey.

In addition to the Water Column TWG sampling, the Marine Mammal TWG also conducted midwater trawls targeting the 400 to 600-m depth zone. The goal of this survey was to gain more information on whale prey species. As this depth zone was covered by the more comprehensive *Pisces* trawl data, only the *Pisces* trawl data was included in the quantification of baseline abundances developed in this report.

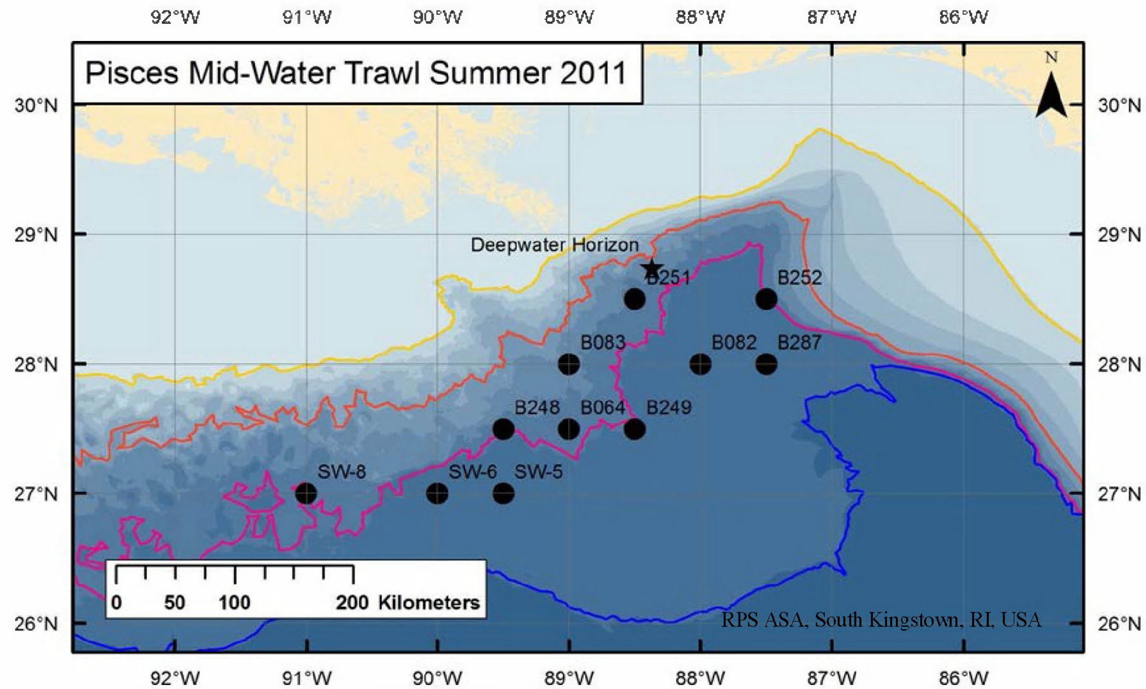

Figure 5-2. Locations of stations sampled for the NRDA Pisces Midwater Trawl survey.

5.2.2 10-Meter^2 MOCNESS

The NRDA 10-m^2 MOCNESS surveys sampled from the same set of 45 SEAMAP stations as the 1-m^2 MOCNESS surveys (Figure 5-1, purple dots). This survey was designed to mimic the goals of the 1-m^2 MOCNESS survey but to address a larger size class of organisms: micronekton and large invertebrate plankton. The 10-m^2 MOCNESS surveys sampled to full ocean depth at all stations. The lowest depth bin was modified at each station based on depth, but the remaining bins were standard and matched to as many of the interval breaks as possible that were employed on the 1-m^2 MOCNESS surveys.

The NRDA 10-m^2 MOCNESS sampling events included cruises in January-March 2011 (*Meg Skansi* Winter 2011), April-June 2011 (*Meg Skansi* Spring 2011), and July-September 2011 (*Meg Skansi* Summer 2011). The sampling scheme for each cruise can be found in the individual cruise plans; the predominant scheme was to deploy the MOCNESS to full ocean depth or 1,500 m (whichever was shallower) and retrieve it collecting samples over prescribed depth bins. Each station was sampled once during the day and once at night.

5.2.3 Epipelagic Sampling

Quantitative data on epipelagic fishes is rare; these species are fast-moving and often caught by fishermen using time- and resource-intensive techniques. As such, little quantitative, fisheries-independent, information is available on them. Nonetheless, they are an important part of the community. One NRDA cruise was conducted September-October 2011 (*McArthur II*) to sample this group of fish. This survey utilized an epipelagic trawl, a towfish outfitted with echosounders and an acoustic camera, personnel for surface water observations, and was paired with an airborne LIDAR (LIght Detection and Ranging) survey. By combining sampling methods of different scales, the goal was to gather quantitative information about the species that reside in the offshore epipelagic environment. The different methods were conducted at various rates and locations throughout the cruise; see the cruise plan for more details.

5.2.4 Pelagic Megafauna

To assess the more fragile planktonic and slow-moving pelagic species in the offshore environment, that are also visible and identifiable in underwater video, an ROV survey was conducted. This survey, led by a BP contractor (Mark Benfield of Louisiana State University) who conducted similar surveys for BOEM in previous years, targeted previously surveyed stations and conducted video transects in the water column and at the sea floor; see the cruise plan for more details (*HOS Sweetwater* 3 and 5, June and August 2011). The data from this survey has not yet been released; however, it could help fill the data gap for those species that are destroyed or not readily caught by net/trawl sampling.

6 Use of Net Tow and Trawl Data to Estimate Abundance and Biomass of Fish and Invertebrates

6.1 Selection of Biological Datasets Used to Develop Baseline Abundances and Biomass

From the historical studies that are described in Section 4 above, those that were available at the time of the analysis and were most useful in deriving baseline estimates for plankton, juvenile and adult fish and invertebrates potentially affected by the spill included the SEAMAP Ichthyoplankton, SEAMAP Invertebrate Zooplankton, FOCAL program plankton, SEAMAP Shrimp/Groundfish Trawl Surveys, and the Deep Gulf of Mexico Benthos Survey (DGoMB). These datasets were augmented with NRDA datasets (available by October 2014) and additional historical data in order to more completely quantify the abundances of fish and invertebrate species and life stages occupying the northeastern Gulf of Mexico (GOM). Since each survey and sampling gear only captures certain size ranges and stages of fish and invertebrates, and the historical surveys focus on specific geographic areas and depth ranges, we sought to identify data that sampled other areas and size ranges of organisms.

The following biological datasets were chosen to construct baseline density estimates because they provided standardized, quantitative insight into marine organisms in all areas and depths of the GOM, at various life stages. Table 6-1 summarizes the datasets covering different ecozones and depth ranges. While the following datasets were used to calculate baseline density estimates, only ichthyoplankton and invertebrate zooplankton were used for injury quantification. Of these datasets listed below and in Table 6-1, those used for injury quantification included: SEAMAP Ichthyoplankton Survey, SEAMAP Invertebrate Zooplankton Survey, NRDA Plankton Bongo Survey, NRDA Plankton 1-m^2 MOCNESS, NRDA 10-m^2 MOCNESS, and the FOCAL Program data (Appendix E). The other datasets not used for injury quantification provided baseline estimates for other fish and invertebrate nekton of various life stages in the GOM.

- Fish
    - Ichthyoplankton
        - SEAMAP Ichthyoplankton Survey (1999-2009) – for eggs, larvae and small young-of-the-year juvenile fish in the upper 200 m on the shelf and offshore;
        - FOCAL program plankton samples using Mininess (2007-2009) – for fish eggs and larvae in estuarine waters inside of the along-shore barrier islands;
        - NRDA plankton 1-m^2 MOCNESS samples (2011) – for fish larvae below 200 m in offshore waters;
    - Pelagic and Demersal Nekton
        - SEAMAP Shrimp/Groundfish Survey – for juveniles and adults of smaller and slower-swimming fish occupying the shelf (<200 m), primarily demersal but including some pelagic species;
        - NRDA Flying Fish Observations (2011) – for juvenile and adult fish in surface waters on the shelf and offshore;
        - Stock Assessment-Based Estimates – for juvenile and adult fish in shelf and offshore waters

    - NRDA 10-m^2 MOCNESS samples (2011) – for micro-nektonic pelagic fish in all depths of offshore waters (>200 m deep)
    - NRDA Pisces Midwater Trawl (2011) – for nektonic pelagic fish in all depths of offshore waters (>200 m deep)
    - MMS Deep Gulf of Mexico Benthos Survey (DGoMB, Powell et al. 2003) – for demersal fish on the continental slope (>200 m)
    - Nearshore fish (Brown et al. 2013) – in nearshore estuarine waters
- Invertebrates
  - Plankton
    - SEAMAP Invertebrate Zooplankton Survey (1999-2009) – for microzooplankton other than decapods in the upper 200 m on the shelf and offshore
    - FOCAL program plankton samples using Mininess (2007-2009) – for microzooplankton in estuarine waters inside of the along-shore barrier islands;
    - NRDA plankton bongo samples (2011) – for decapod larvae in upper 200 m in shelf waters and offshore
    - NRDA plankton 1-m^2 MOCNESS samples (2011) – for decapod larvae below 200m in offshore waters
    - NRDA 10-m^2 MOCNESS samples (2011) – for medium-size planktonic invertebrates in all depths of offshore waters (>200 m deep)
    - NRDA Pisces Midwater Trawl (2011) – for large planktonic invertebrates in all depths of offshore waters (>200 m deep)
  - Pelagic Nekton
    - SEAMAP Shrimp/Groundfish Survey (1999-2009) – for invertebrates occupying the shelf (<200 m), primarily demersal but including some pelagic species
    - NRDA Pisces Midwater Trawl (2011) – for small nektonic invertebrates in all depths of offshore waters (>200 m deep)
    - Nearshore invertebrates (Brown et al. 2013) – for decapods in nearshore estuarine waters
  - Demersal and Benthic Megafauna (in unstructured habitat)
    - SEAMAP Shrimp/Groundfish Survey (1999-2009) – for demersal and benthic megafauna occupying the shelf (<200 m)
    - MMS Deep Gulf of Mexico Benthos Survey (DGoMB, Rowe and Kennicutt II 2009) – for demersal and benthic megafauna occupying the continental slope (>200 m)

These datasets quantify abundances and standing biomass for planktonic stages and species of fish and invertebrates in all depths and areas in the assessment region. Demersal species and stages are also well sampled and characterized. The offshore pelagic sampling captured micro- and small nekton, but catchability of large and fast-swimming nekton was likely very low. For example, the pelagic sampling gears did not capture a single flying fish, a common fast-swimming pelagic species, yet shipboard observers on NRDA cruises were able to count flying fish in large numbers as they flew from the water. Thus, flying fish and other fast-swimming pelagics were not captured or quantifiable using the sample gears available. Pelagics on the shelf were only sampled in the bottom 1 meter of the water column in the SEAMAP Shrimp/Groundfish Survey. Thus, they were likely under-represented in the samples and their areal biomass estimates (made by correcting for the fraction of the water column sampled) are therefore underestimated. For these reasons, pelagic fish abundance and biomass estimates were sought from stock assessment analyses, allowing baseline estimates to be made for these species.

Subsets of the long-term monitoring datasets (i.e., certain years, seasons, gear types, and locations) were chosen for increased data accuracy (e.g., to maintain consistent sampling and identification protocols over years) and for relevance to the assessment region and the seasons where direct effects were expected (spring to early fall). Additionally, an effort was made to maintain consistency in spatial and temporal analyses across datasets for comparable results (such as examining samples from the same month, years and areas over multiple surveys).

Finally, species names presented in these reports were based on the taxonomy provided in the source datasets; however, edits were made as necessary to correct misspellings or inconsistencies and update changes in taxonomy. The changes are described in the dataset-specific subsections in Section 7. Scientific names presented in this report are up-to-date as of 2014.

Table 6-1. Biological Data Sources Used to Derive Aquatic Biota Abundance and Biomass.

Water Column Depth	Nearshore (< 7m)	Shelf (7 - 200 m water depth)	Offshore (> 200 m water depth)
0 - 200 m	• FOCAL Ichthyo-plankton and micro-zooplankton • Nearshore Louisiana Surveys (Brown et al. 2013)	• SEAMAP Ichthyoplankton Survey • SEAMAP Invertebrate Zooplankton Survey • NRDA Plankton Bongo Survey • SEAMAP Shrimp/Groundfish Survey • NRDA Flying Fish Observations • Stock Assessment Data	• SEAMAP Ichthyoplankton Survey • SEAMAP Invertebrate Zooplankton Survey • NRDA Plankton Bongo Survey • NRDA 10-m^2 MOCNESS • NRDA Pisces Midwater Trawl • NRDA Flying Fish Observations • Stock Assessment Data
> 200 m			• NRDA 1-m^2 MOCNESS • NRDA 10-m^2 MOCNESS • NRDA Pisces Midwater Trawl • Deep Gulf of Mexico Benthos (DGoMB)

6.2 Model of Expected Abundance, Densities and Uncertainty

6.2.1 Vertically-Integrated Abundance and Biomass versus Density per Unit Volume

As a first step, the plankton datasets were processed to develop numerical abundance or biomass per unit area sampled. Based on the nature of the measurements and reporting of the original data of Catch per Unit Effort (CPUE), numerical abundance was estimated from counts per unit effort or biomass per unit effort was estimated based on sample weights and identifications. For bongos and Mininess, the depth interval sampled was from 200 m, or the sea floor if shallower than 200 m, to the surface. For the MOCNESS sampling, depth intervals over which the abundances were integrated varied, but were between the surface and down to 1,500 m in the deeper offshore areas. Thus, the calculated abundance data were expressed as numbers per area sampled, integrated over the depth range sampled. Similarly, biomass was integrated over the depth range sampled.

In the second step, the vertical distributions of plankton were evaluated to estimate the volumetric densities (# m^{-3}) of organisms within the broad depth ranges sampled by the gear used to quantify abundance. For example, the SEAMAP plankton program sampled plankton using bongos deployed from 200 m (or from just above the sea floor on the shelf and nearshore) to the surface, but many of the species captured actual occupy narrower depth ranges. For example, many fish larvae occupy the upper 40 m of the water column, and so in deep water a 200 m bongo sample would have primarily captured individuals in the upper-most 40 m of the tow. Therefore, the density of organisms known to principally inhabit the upper 40 m is appropriately the integrated density divided by 40 m (as opposed to 200 m), yielding number per m^3.

The analysis and assignment of depth ranges for plankton is described in French McCay et al. (2015a). Available depth-discrete data sets collected by MOCNESS were used to evaluate vertical depth ranges. The SEAMAP historical 1-m^2 MOCNESS, NRDA 1-m^2 MOCNESS, and NRDA 10-m^2 MOCNESS datasets included sufficient sampling locations and net samples to evaluate vertical depth ranges of plankton. Vertical ranges for plankton, both fish (ichthyoplankton) and invertebrate, were assigned to encompass 95% of their abundances in MOCNESS samples. (See French McCay et al. 2015a for further details).

6.2.2 Methods for Calculating Averages and Uncertainty Ranges

Arithmetic means and uncertainty ranges were estimated from the integrated abundance and biomass data (i.e., from CPUE data). Two overall approaches were used for determining expected numbers/biomass of fish and invertebrates, and the associated uncertainty. These are:

1) Calculating seasonal or monthly arithmetic means and percentiles with a bootstrapping technique, for estimating expected numbers/biomass in defined geographic regions, and
2) Using spatially explicit generalized additive models (using in situ samples and environmental variables to construct predictive models describing ichthyoplankton abundances spatially and temporally).

For more detail on the second approach using spatially explicit general additive models, refer to Christman and Keller (2015). This method was only implemented with the SEAMAP Ichthyoplankton historical dataset.

Seasonal, monthly, or 6-month (April-September) arithmetic means, and associated uncertainty ranges, were calculated for several of the selected datasets to develop baseline estimates: SEAMAP Ichthyoplankton Survey (for larvae and juvenile fish), FOCAL Ichthyoplankton and Micro-zooplankton, SEAMAP Invertebrate Zooplankton Survey, SEAMAP Shrimp/Groundfish Survey, MMS Deep Gulf of Mexico Benthos Survey (DGoMB, Powell et al. 2003; Rowe and Kennicutt II 2009), NRDA plankton samples using bongos and 1-m^2 MOCNESS tows, NRDA Pisces Midwater Trawl and 10-m^2 MOCNESS tows. For details on the aggregation and calculations of these datasets, please refer to Section 7 of this report.

For the catch per standardized effort (number of individuals or biomass / area) of each dataset, arithmetic means were calculated for each analysis taxon using the following equation:

$$CPUE_F = \frac{\sum_{i=1}^{n} CPUE_S}{n}$$

where $CPUE_S$, is catch (in biomass or number of individuals) per unit effort (typically volume filtered or swath of area) in each of the *n* number of samples. Final mean CPUE estimates ($CPUE_F$) were calculated over all samples in a wide form data table (survey sample by species or analysis taxa, with $CPUE_S$ as values). In the event that an analysis taxon was not found in a given survey, a zero was used for the abundance/biomass. Thus, in a given survey, all species had the same *n* with zeroes indicating their absences in a given trawl.

A bootstrapping technique was also performed on each wide form dataset to obtain the 2.5th and 97.5th percentiles for each species, based on the procedures in Efron and Tibshirani (1993). For the bootstrapping, 1,000 bootstrap samples using simple random sampling with replacement were obtained for CPUE in each dataset. The 2.5 and 97.5th percentiles were then calculated for the 1,000 bootstrapped seasonal means for each species to provide confidence limits for the CPUE estimates (at the 95% level).

Subsequent to the calculation of the CPUE estimates, catchability corrections were made (where possible, see Section 6.3) and, in the case of plankton, volumetric densities were calculated as catchability-corrected CPUE divided by the depth range of the taxa (from French McCay et al. 2015a). Catchability and depth range corrections did not have uncertainty ranges associated with them, and were considered mean or static corrections. Thus, the final confidence intervals only represented in the uncertainty from the samples and not additional uncertainty derived outside of the CPUE dataset.

6.3 Catchability

CPUE estimates for marine organisms are often underestimates of the true population due to a variety of factors (e.g., inefficiencies of the sampling gear or boat, avoidance of the net, time of day of sampling that may influence avoidance, lack of availability due to spatial and temporal distributions). Catchability scalars may be used to correct CPUE for some of these under-sampling factors. Several of the datasets used for the analyses of baseline have applied catchability correction factors, varying by survey and species. Prior to developing the catchability scalars used herein, we performed a review of catchability analyses in the published literature (see Appendix B). The catchability scalars used are described in Section 7 for each dataset. Note that not all data sets are corrected for catchability, and for those that are, not all under-sampling factors could be quantified.

7 Biological Datasets Used for Calculation of Baseline Estimates

This section describes the data aggregation and filters used to derive fish and invertebrate baseline estimates for 2010 from each dataset. The data sources (listed in Section 6.1) vary in geographic extent from shore and by depth gradient represented by each (Table 6-1). Descriptions of data processing and calculations for analysis taxon are provided below.

7.1 SEAMAP Ichthyoplankton Survey (Fish Larvae and Small Juvenile Fish)

The NMFS SEAMAP Ichthyoplankton Survey was the primary data source for deriving ichthyoplankton baseline estimates. Sampling has been conducted over multiple seasons annually, including spring and summer since 1982, fall since 1986, and winter over several years since 1983. Data from this survey were used to produce fish larval and post-larval/juvenile baseline estimates via two different methods: mean CPUE directly calculated from the database and CPUE predicted for the spring and summer of 2010 using generalized additive models.

7.1.1 Mean SEAMAP Ichthyoplankton Abundance

SEAMAP Ichthyoplankton Survey data were provided by David Hanisko of the NMFS Southeast Fisheries Science Center (SEFSC) Pascagoula Laboratory in November 2013. The data used to derive baseline estimates included samples collected from April to September, in the years 1999 to 2009, and within the geographic range between 27-31ºN and 87-92ºW (Figure 7-1). Samples are generally taken by the SEAMAP Ichthyoplankton Survey from regular gridded stations that are approximately 30 nm apart; however, several samples were taken between grid points over the shelf in the spring and fall as part of the SEAMAP Shrimp/Groundfish Survey. Figure 7-2 shows the geographic extent and survey station locations for the spring and summer SEAMAP Plankton Survey data used to derive ichthyoplankton baseline estimates.

The SEAMAP ichthyoplankton survey data provided by NMFS SEFSC included three sampling gears: the 333 µm (0.333 mm) mesh bongo (double or single, sampled to just above the seafloor bottom on the continental shelf or to a maximum water depth of 200 m off the shelf); the 946 µm (0.946 mm) mesh rectangular frame neuston net (double or single, towed half-submerged at the surface), and, since 2007, the 505 µm (0.505 mm) mesh 1-m^2 MOCNESS. Only the 333 µm mesh bongo data were used to derive the ichthyoplankton baseline estimates. The neuston samples were examined, but because the volume sampled was not measured by a flow meter (as is the case with the bongo samples), and would need to be estimated from ship speed and time towed, we used the bongos exclusively to not double-count taxa appearing in both gears. Nearly all of the taxa appearing in the neuston samples also appeared in the bongo samples. The 1-m^2 MOCNESS samples were not combined for baseline abundance estimation because the mesh size and catchability of fish larvae were different than for the bongos.

For this survey, NMFS SEFSC sorts and identifies the ichthyoplankton collected to family or lowest taxon possible (depending on species). Additionally, the lengths of some ichthyoplankton taxa have been measured, typically for a subsample of individuals counted.

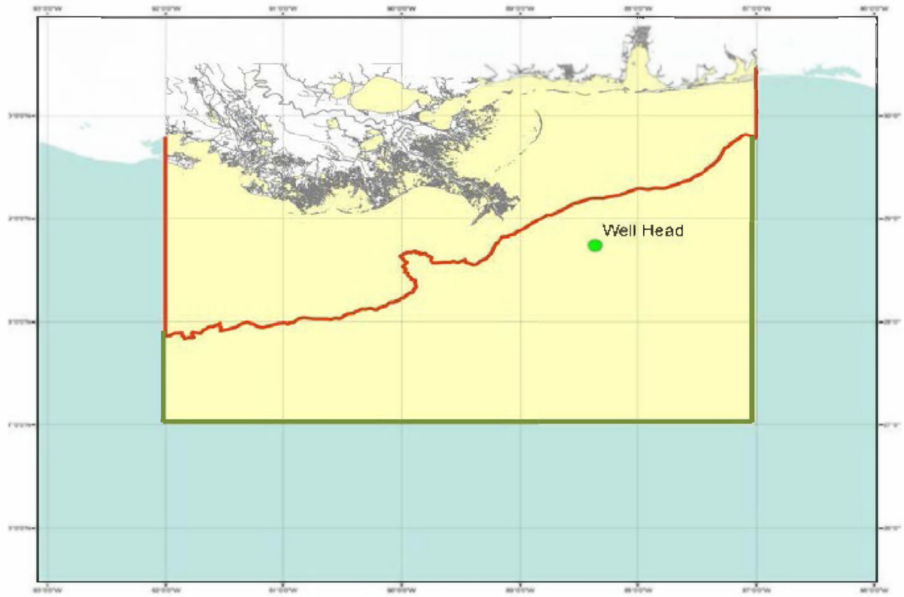

Figure 7-1. Assessment region used to derive ichthyoplankton abundances. Bold red line through the assessment region represents the 200-m bathymetry contour.

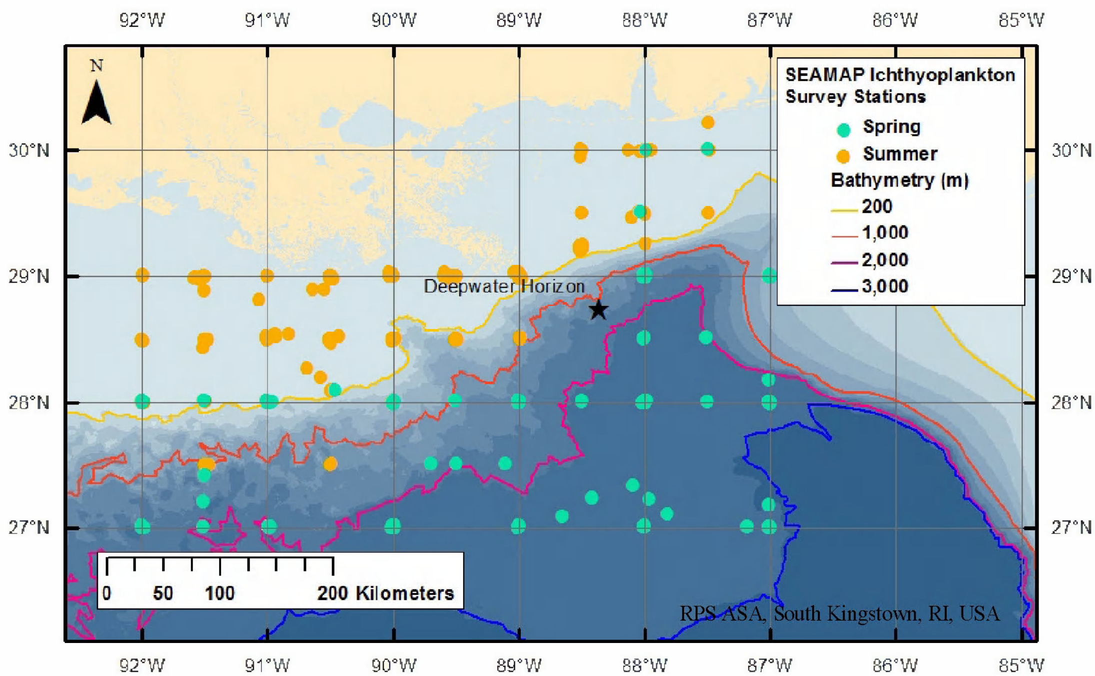

Figure 7-2. Geographic extent and survey station locations of SEAMAP Plankton Survey data used to derive ichthyoplankton abundances.

7.1.1.1 **Data Processing**

Bongo samples collected between the years 1999 and 2009 and within the coordinate grid of 27-31ºN and 87-92ºW (Figure 7-1) were isolated. Data were then grouped into four distinct sub-datasets based on seasonality (spring and summer) and distance to shore (inshore and offshore). Spring was classified as samples collected in April, May and June, while summer included samples collected in July, August and September. Inshore (i.e., shelf) was defined as stations within the 200-m bathymetry contour, while offshore included samples in waters with bathymetry greater than 200 m. Thus, four separate datasets from the SEAMAP Ichthyoplankton Survey were constructed: Spring Inshore, Spring Offshore, Summer Inshore, and Summer Offshore. The total number of samples in each dataset is provided in Table 7-1.

Table 7-1. Number of samples in each of the subsets constructed from the SEAMAP ichthyoplankton database.

Aggregation of SEAMAP Ichthyoplankton Data	Number of Samples in Dataset
Spring Inshore (Shelf)	108
Spring Offshore	186
Summer Inshore (Shelf)	412
Summer Offshore	75

7.1.1.2 **Taxa Description**

Ichthyoplankton CPUE means and uncertainty ranges were calculated at an 'analysis taxa' level. Analysis taxa were identified at taxonomic levels that scientists at the SEFSC were confident in their identification. Constructing these analysis taxa resulted in collapsing certain taxa's counts together for a broader, more inclusive taxonomy. Analysis taxa were constructed based on a relational table that contained all taxa from the SEAMAP Ichthyoplankton dataset and the complete current ITIS (Integrated Taxonomic Information System) classifications for all taxonomic levels. This table was provided by David Hanisko and Joanne Lyczkowski-Shultz (NMFS SEFSC). Taxa varied in level of identification, including orders, families, genera and species. Several analysis taxa at the family and genus level included organisms that were originally identified past that level of classification, but were then grouped to the broader taxa based on suggestions in the 'Parent Matrix' (e.g., *Cynoscion* sp.*, Cynoscion nothus and Cynoscion arenarius* were all grouped to *Cynoscion* sp.). Some orders, families and genera included organisms that were only identifiable to that same level (i.e., Anguilliformes only included organisms identifiable to Anguilliformes). No organisms were double counted based on the taxonomic groupings. At the suggestion of SEFSC, all Atlantic bluefin tuna (*Thunnus thynnus*) caught after June were grouped to the genus level *Thunnus* sp. because of SEFSC laboratory skepticism that the individuals were truly Atlantic bluefin tuna (based on the documented migration out of the Gulf of Mexico by the end of June of adults that could have produced larvae). There were a total of 220 analysis taxa examined over each Spring/Summer Inshore/Offshore Ichthyoplankton dataset.

7.1.1.3 **Abundance Calculations**

Standardized abundances as number per square kilometer (# km^{-2}) were calculated for taxa from the bongo samples using the aliquot (fraction of the sample actually counted), volume filtered by the net, and depth range sampled:

$$CPUE = \frac{Total\ Count * Larval\ Multiplier}{Volume\ Filtered} * Z * 10^6$$

where Z is depth to which the bongo net sampled (m, all bongos sampled to the water surface), volume filtered is amount of water that passed through the net (m^3) and the larval multiplier is the inverse of the aliquot. For each dataset (i.e., the Spring/Summer by Inshore/Offshore matrix), mean CPUE and percentile confidence limits were calculated for each analysis taxa as described in Section 6.2. CPUE estimates were then split into two groups: larvae (considered plankton, which are transported by currents) and post-larvae/juveniles (nekton, active swimmers that can move fast enough to not be transported by currents). The construction of these proportions using length measurements are described in Section 7.1.1.4.

7.1.1.4 **Length Calculations**

To determine the portion of the total mean and percentile CPUE of analysis taxa to be classified as larvae versus post-larvae/ juvenile (hereafter in this section referred to as juvenile), length measurements from the SEAMAP Ichthyoplankton bongo samples (1999-2009, between 25-31°N and greater than 81.5°W) were used. As part of the sampling program, ichthyoplankton lengths were measured to the nearest 0.1 mm. Length measurements were excluded when only 2 larvae of a taxon in a sample were measured but had more than 0 individuals not measured. These measurements were excluded because they reflected minimum and maximum length measurements only, which would distort length and age frequency distributions of the true population. Measurements for taxa were split between spring and summer (as described in Section 7.1.1.1), but with no bathymetry delineation. The length information for each taxon was then cross-tabulated by length measurement to construct a tabular frequency distribution of counts by length (mm).

Using larval growth models from Pepin (1991) (see Production Foregone Model Report; French McCay et al. 2015b), which estimated size at the end of the larval stage, ichthyoplankton less than or equal to 20.15 mm in the spring and 23.33 mm in the summer were classified as larvae. Those with lengths greater than these thresholds were classified as juveniles. Proportion of lengths below and above the seasonal length thresholds from the total length measurements for the taxon (Appendix C) were calculated for each analysis taxa. With these percentages, the SEAMAP Ichthyoplankton CPUE (mean, 2.5, and 97.5th percentiles) were multiplied by the larval and juvenile percentages to produce actual larvae and juvenile abundances (Appendix D). Additionally, median length measurements were calculated for both the larval and juvenile populations (for use in production foregone calculations, see French McCay et al. 2015b).

7.1.1.5 **Modal Age Calculations**

Length measurements from the tabular length frequency information were converted to daily ages to determine the modal age of the true larval population. Larval lengths were converted to ages (in days) using the growth rate equation from Pepin (1991) (see French McCay et al. 2015b). Tabular age-frequency data were then compiled, with ages rounded down to the nearest whole day. After compiling age-frequency information for the larval population, the mode of the age class frequency distribution and their proportions of the larvae population were calculated for each taxon. These results provided information on the most efficiently caught (or best sampled) larval daily age class. The proportions of the modal age classes of the total larval abundance provided a scalar to determine the modal age-specific abundances. Modal age abundances were calculated by multiplying the modal age proportions by the total larval CPUE (as described in 7.1.1.4). As performed with the lengths, modal ages and proportion of modal age for the population were calculated for spring and summer respectively. If there were instances where a taxa had modal age information for one season but not the other, length measurements for that season were used with the spring growth model (i.e., the 20.15 mm larval/juvenile threshold was used) to determine the modal age class and proportion. Modal age, length at the model age, and proportion of the abundance that were larvae are presented in Appendix D for each analysis taxa.

In addition to fish larval length at the modal age, wet weight at modal age was calculated according to the following length-wet weight (Davis and Wiebe 1985) conversion equation:

$$W = 0.0069L^{2.886}$$

where *W* is wet weight (mg), and *L* is length (mm).

7.1.2 Generalized Additive Models (GAMs) - SEAMAP Ichthyoplankton Abundances

Generalized additive models (GAMs) are nonparametric regressions that use several smooth additive functions to produce curvature or splines in the predictions (Hastie & Tibshirani 1986; Wood 2006). The GAM approach has been used to model the spatial distribution of marine organisms under varying conditions, both in the Gulf of Mexico and worldwide (Weber and McClatchie 2012; Drexler & Ainsworth 2013; Reglero et al. 2014). Christman and Keller (2015) used SEAMAP Ichthyoplankton sample data with covariates at respective samples' times and locations to construct taxa-specific GAMs and predict abundance (# $100m^{-2}$) at 10 day intervals during spring and summer 2010 (the 15th and 30th of April-August). Covariates used in modeling include *in situ* oceanographic sample measurements, field information, celestial data, and satellite products. For models where a Day/Night variable was included, 'Night' was used as the input to predict abundances accounting for larval net avoidance. For a complete description of the SEAMAP Ichthyoplankton and covariate data used and modeling approach, please refer to Christman and Keller (2015).

7.1.2.1 Proportion at Modal Age

Modal ages and proportions at modal age were also calculated for use with calculated GAM abundance. Larval length and age processing were conducted using the same methodology as for the Mean Ichthyoplankton Abundances (Sections 7.1.1.4-5). However, for GAM processing, larvae and juvenile abundances were not separated based on size thresholds (as done for the Mean abundances) because the GAMs were constructed for the entire SEAMAP Ichthyoplankton population (i.e., both larvae and post-larvae/juveniles combined). Additionally, the abundance data set used by Christman and Keller (2015) for the GAMs covered the same geographic area used for the length data (25-31ºN and greater than 81.5ºW), thus the models were built on data for a region much larger than our assessment region (Figure 7-1) .

7.2 SEAMAP Invertebrate Zooplankton Survey

RPS ASA received the SEAMAP Invertebrate Zooplankton data from the NMFS SEFSC Pascagoula Laboratory in two phases; in July 2011 and in September 2012. The SEAMAP Invertebrate Zooplankton Survey data included three gear types: neuston (0.995 mm mesh), bongo (0.333 mm mesh), and MOCNESS (0.505 mm mesh). Only the bongo gear data were used to derive invertebrate zooplankton CPUE and biomass because bongos had the smallest mesh size, thus best capturing the smallest plankton, and sampled the entirety of the water column (or to a max depth of 200 m). There is information available in peer reviewed literature regarding catchability of invertebrate zooplankton in 0.333 mm mesh plankton nets, which was used to correct the CPUE data. A further discussion of literature on catchability for this mesh size is provided in Appendix B.

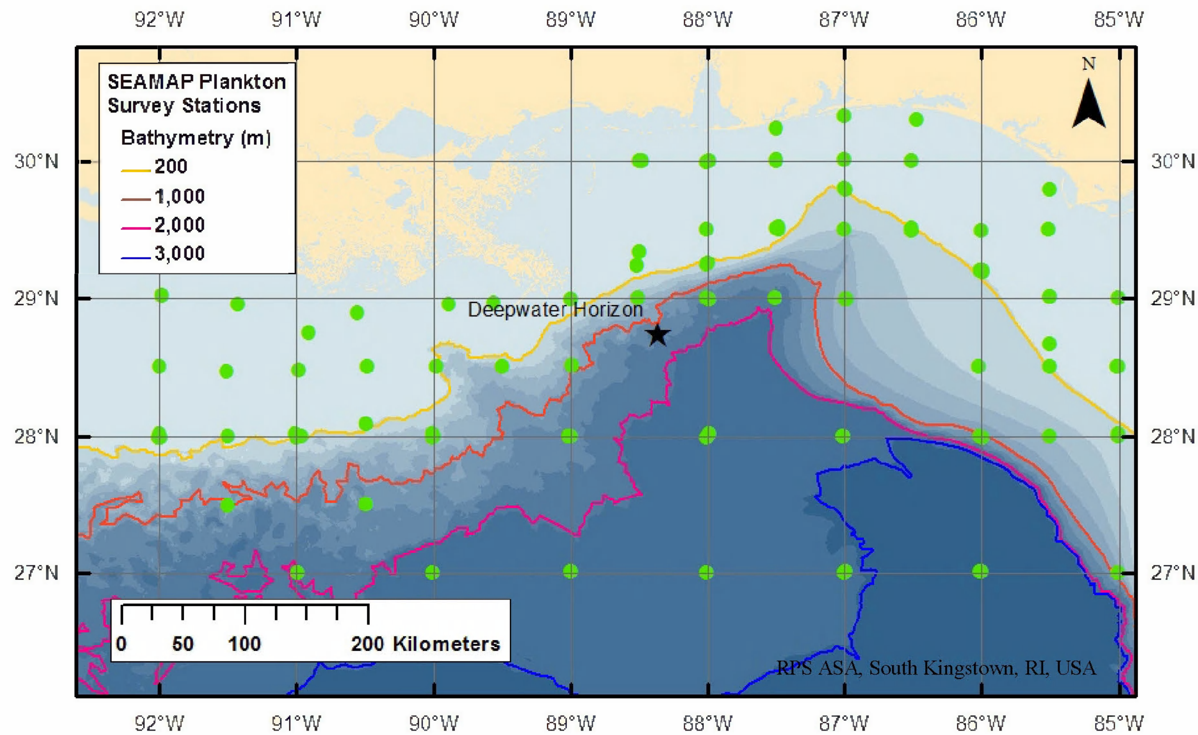

Figure 7-3. Geographic extent and survey station locations (green dots) of SEAMAP plankton survey data used to calculate invertebrate zooplankton baseline estimates.

In order to increase the number of samples (particularly for the spring season) available to calculate invertebrate zooplankton abundance and biomass, a slightly wider assessment region (north of 27ºN and from 85ºW to 92.5ºW) than the region used to derive ichthyoplankton abundances was used. As with the ichthyoplankton analyses, only data from 1999-2009 were included in the analysis. Table 7-2 provides the number of samples by season for the inshore (shelf) and offshore areas. As for ichthyoplankton, spring was defined as April, May and June, while summer included July, August and September.

Table 7-2. Number of samples in each of the spatiotemporal subsets constructed from the SEAMAP invertebrate zooplankton survey.

Aggregation of SEAMAP Ichthyoplankton Data	Number of Samples in Dataset
Spring Inshore (shelf)	18
Spring Offshore	49
Summer Inshore (shelf)	81
Summer Offshore	14

Refer to Appendix D for a complete list of the analysis taxa used to calculate baseline abundances and biomass from the SEAMAP Invertebrate Zooplankton Survey.

7.2.1 Data Processing

The original SEAMAP zooplankton data are comprised of numbers of individuals identified to various taxonomic levels, typically at the level of order or higher. Larval penaeid shrimp and portunid crab CPUE from SEAMAP Invertebrate Zooplankton dataset were not included in analyses because these taxa were represented in the NRDA Plankton Survey (bongos in the upper 200 m) at a much finer taxonomic resolution (Section 7.3). Thus, including them would lead to double representation of the species at that life stage in the baseline dataset.

To calculate the wet weight of a taxon, the numbers of individuals were converted to biomass (kg) by multiplying by estimated average weight (kg) per individual. Length-weight relationships for Gulf of Mexico zooplankton taxa were derived from Davis and Wiebe (1985). The average weight per individual was calculated from the average length by taxon, as indicated in Johnson and Allen (2005) and shown in Table 7-3.

Table 7-3. Average weight per individual invertebrate zooplankton taxon used to convert numbers of individuals to biomass.

SEAMAP Species Group	Wet Weight per Individual (mg)
Amphipods, Isopods	0.286
Bivalves	0.022
Calanoid copepods, Cyclopoid copepods, Harpacticoid copepods, Lophophores, Unidentified zooplankton	0.086
Cephalopods	1.571
Chaetognaths	1.574
Cladocerans, Ostracods	0.091
Ctenophore larvae, Hydromedusae	5.020
Doliolids, Salps, Siphonophores, Calycophora	15.708
Euphausiids, Mysid shrimp, Stomatopods	0.300
Gastropods, Heteropods	0.397
Larvaceans	0.040
Barnacles, Echinoderms	0.100
Polychaetes	0.009
Pteropods	0.012

CPUE for invertebrate zooplankton were calculated as number per area (m^2) using each samples' volume filtered and depth measurements. Mean abundances and bootstrapped percentile ranges were then calculated for the invertebrate zooplankton taxa. Arithmetic means and bootstrapped percentiles were converted from abundances (number per m^2) to biomass (kg/km^2), as described above.

7.2.2 Catchability Correction

Because extrusion of smaller planktonic organisms (such as zooplankton) is substantial in 0.333 mm mesh plankton nets (Appendix B), catchability coefficients were applied to each analysis taxon from the SEAMAP Invertebrate Zooplankton Survey (Table 7-4). Extrusion values were derived from Colton et al. (1980) and Remsen et al. (2004). When an analysis taxon from the SEAMAP Invertebrate Zooplankton Survey data was not represented in these two studies, the extrusion coefficient (q) was made equal to 1.

Several publications indicate that some species groups of invertebrate zooplankton actively avoid an approaching net, especially decapods (Angel and Pugh 2000) and euphausiids (Wiebe et al. 1982; Sameoto et al. 1993; Marschoff et al. 1998; Angel and Pugh 2000). However, evidence of avoidance in other species groups (e.g., chaetognaths, ostracods, pteropods, siphonophores, ctenophores, etc.) is lacking. Kane (2009) notes that larval invertebrates likely use non-visual cues to sense the pressure wave caused by an approaching net; however, characterizing the pressure wave would require an understanding of all hydrostatic forces in effect. If it were possible to quantify the pressure wave created by the specific materials and configuration of the SEAMAP bongo gear and sampling protocols, it would be similarly difficult to quantify the reactions of invertebrate zooplankton to that pressure wave. A more time efficient method to estimate behavioral avoidance and to better estimate true plankton abundances is to explore the degree of avoidance occurring due to visual cues. For some species of invertebrate zooplankton, if they are able to see the net approaching during the day and swim out of the net's path, then catches of those species should be higher during the night. Analyses such as this can be done by comparing day and night catch data.

Mean night and day densities (# m^{-3}) were compared for the invertebrate zooplankton taxa to determine potential net avoidance. If the day and night means plus or minus their standard errors did not overlap, the taxa was defined as exhibiting avoidance. Five taxa were found to be more abundant at night than during the day. For these taxa, the vulnerability q (V_B) was calculated as the mean density from all samples divided by the mean night time density. All other analysis taxa were assigned a vulnerability q (V_B) of 1 due to behavioral avoidance. Table 7-5 provides the vulnerability due to behavioral avoidance (V_B) per analysis taxa.

Final catchability coefficients by analysis taxa for the SEAMAP Invertebrate Zooplankton were calculated by multiplying the extrusion and vulnerability components (V_B x V_E), as listed in Tables 7-4 and 7-5. The uncorrected and catchability-corrected areal biomass estimates of zooplankton are tabulated in Appendix D.

Table 7-4. Vulnerability from extrusion (V_E) estimates applied to SEAMAP invertebrate zooplankton data. If no estimates were available, q = 1 was assigned. Star (*) indicates assumed value. Total V_E is the product of the Colton et al. (1980) and the Remsen et al. (2004) extrusion values. V_E scales CPUE using the 0.333 mm mesh to what would be found using a SIPPER (i.e., a more accurate abundance representation.)

Taxon	Representative Taxon from Colton et al. 1980	Colton et al. 1980: CPUE 0.333 mm/ 0.253 mm mesh	Representative Taxon from Remsen et al. 2004	Remsen et al. 2004: CPUE 0.162 mm/ SIPPER	Total V_E
Amphipods	Amphipoda, Hyperia spp., adult and juveniles	0.39	NA	1	0.39
Cladocerans	Cladocera, Evadne, Podon, Penilia spp., adults	0.43	NA	1	0.43
Euphausiids	Meganyctiphanes norvegica, adult and furcilia	0.43	Decapods and Euphausiids	0.96	0.413
Chaetognaths	Chaetognatha, Hyperia spp., adult and juv	0.73	Chaetognaths	0.67	0.489
Ctenophore larvae and Hydromedusae	NA	1	Cnidarians and Ctenophores	0.07	0.07
Echinoderms	NA	1	Echinoderm Plutei and Bipinnaria	0.32	0.32
Larvaceans	NA	1	Larvaceans	0.33	0.33
Heteropods and Cephalopods	NA	1	Molluscs	1	1
Doliolids and Salps	NA	1	Other tunicates	0.26	0.26
Polychaetes	NA	1	Polychaetea	1	1
Siphonophores	NA	1	Siphonophores	0.49	0.49
Barnacles, Bivalves, Gastropods, Isopods, Lophophores, Ostracods, Pteropods, Stomatopods, Unidentified zooplankton	NA	1	NA	1	1*
Mysid shrimp	NA	1	Decapods and Euphausiids	0.96	0.96
Calanoid, Cyclopoid, and Harpacticoid copepods	Average of all identified copepods, all stages	0.44	Copepods	1	0.44

Table 7-5. Vulnerability from Behavior Avoidance (V_B) Estimates Applied to SEAMAP Invertebrate Zooplankton Data.

Analysis Taxon	Total V_B = All times/Nighttime
Barnacles	0.57
Cladocerans	0.60
Echinoderms	0.36
Mysid Shrimp	0.76
Pteropods	0.71

7.3 NRDA Plankton Surveys

7.3.1 Data Processing and Abundance Calculations

NRDA Plankton Surveys were conducted after the spill to increase spatial and temporal coverage of ichthyoplankton and larval decapod sampling, thus complementing information from the SEAMAP Ichthyoplankton Surveys (see Section 5 for description of the program). Taxa were analyzed to the taxonomic level described by the identification laboratories, as outlined in the NRDA Plankton Survey protocol. Two types of sampling gears were used from the database: bongo nets that sample the water column (or maximum of 200 m) and 1-m^2 MOCNESS nets sampling below 200 m (deep deployments). Thus, the two datasets resulting from the NRDA Plankton sampling are described as NRDA Above 200 m (Bongo) and NRDA Below 200 m (MOC 1-m^2).

7.3.1.1 NRDA Above 200m (Bongo)

Bongo samples were used to quantify decapod abundances above 200 m. Fish taxa from the NRDA bongos were not included to avoid double counting taxonomies already counted in the SEAMAP Ichthyoplankton surveys.

Bongo samples from April through September were included in the abundance calculations but not separated by season (Figure 7-4). Cruises collecting these samples included Bunny Bordelon 6, McArthur II 3, Meg Skansi PC3 and Sarah Bordelon PC3, totaling 109 samples (French McCay et al. 2011a,c; Grabe et al. 2013). Integrated abundances over depth for each sample were calculated as:

$$CPUE\left(\#/_{km^2}\right) = NumberPerVolume\left(\#/_{m^3}\right) * Z * 10^6$$

Z represents the depth (m) which the bongo net sampled. Average NRDA Above 200 m CPUE and percentile confidence limits were calculated as described in Section 6.2.

7.3.1.2 NRDA Below 200m (MOC1m)

Deep 1-m^2 MOCNESS samples were used to determine the abundances of fish and decapod larvae below 200 m. Nets never exceeded depths greater than 2,200 m. Samples from the Walton Smith 4 cruise in April and May 2011 (Figure 7-4; French McCay et al. 2012) were analyzed. Taxa were excluded from these calculations if there was insufficient information to describe their vertical distribution (see French McCay et al. 2015a). CPUE was calculated for each sample/net as:

$$CPUE\left(\#/_{km^2}\right) = NumberPerVolume\left(\#/_{m^3}\right) * \Delta Z * 10^6$$

The depth difference, ΔZ (m), represents the height of the water column sampled by the net. CPUE from discrete nets were then summed by taxa and net deployment to calculate integrated water column abundances. Nets from 0-200 m were excluded from this integration because ichthyoplankton and small decapod abundances above 200 m were represented by the SEAMAP Ichthyoplankton and NRDA bongo samples described above. As a result, there were 20 integrated samples (from 200 m to a maximum sampled depth) used for the calculations. Average abundances and percentile confidence limits were calculated as described in Section 6.2.

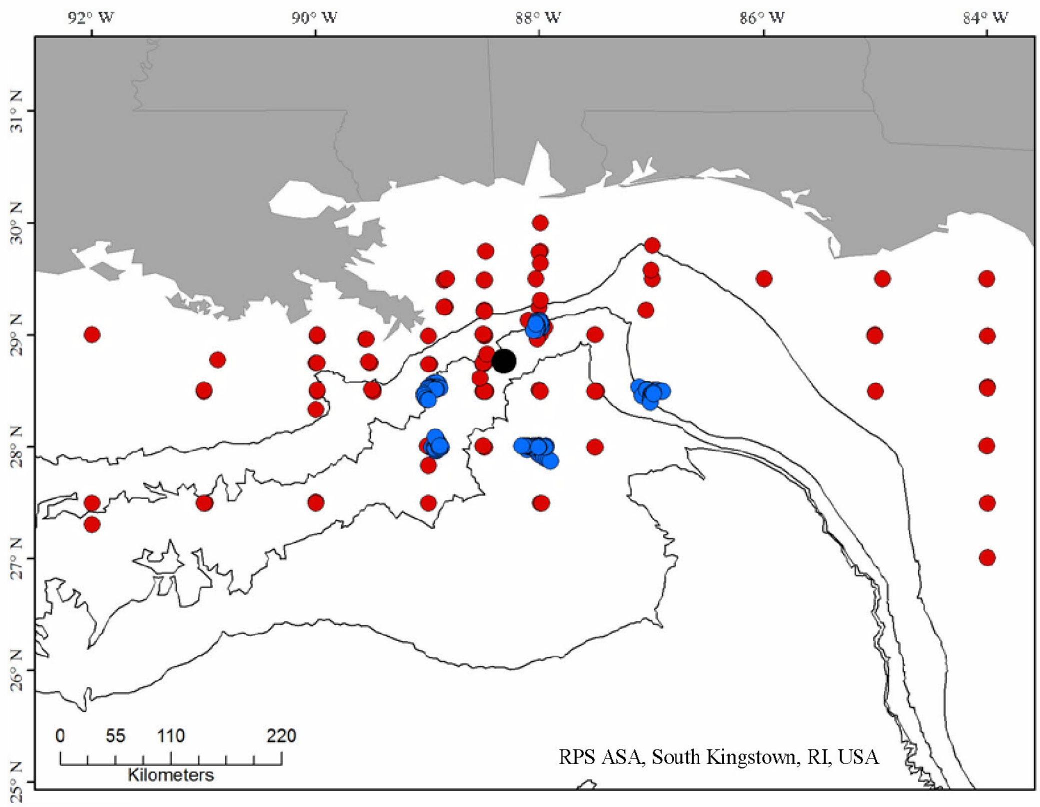

Figure 7-4. Sample locations used from the NRDA Bongo (red, above 200 m) and 1-m^2 MOCNESS (blue, below 200 m) surveys used to assess larval fish and decapods. Note that MOC1 samples reflect the discrete nets; the number of deployments is fewer as several nets make up a deployment. MC252 Wellhead indicated with the black dot. Black lines represent 200 m, 1,000 m, 2,000 m and 3,000 m bathymetry contours.

7.3.2 Length, Weight and Modal Age Calculations

Length measurements were extracted from the same samples used for abundance calculations. Median lengths were calculated for all taxa, representing the 50th percentile length per individual of the population. If a decapod's length information was unavailable, the taxon was assigned a proxy length of 2 mm or 3 mm depending on whether it most resembled a portunid or a penaeid, respectively. To determine the modal size and age classes of the fish larvae caught, length information were processed and calculated as described for the SEAMAP Ichthyoplankton Survey data (Section 7.1.1.4).

Ichthyoplankton weights per individual were calculated using length-wet weight (Davis and Wiebe 1985) conversion equation as described in Section 7.1.1.5. Shrimp and crab weights per individual were calculated using length-weight relationships for individual Gulf of Mexico decapods derived from Wiebe and Davis (1985). Either the penaeid or portunid model was applied to the median length for each decapod:

$$Penaeid: Weight\ (g) = 0.01 * Length\ (mm)^{3.09}$$

$$Portunid: Weight\ (g) = 0.0172 * Length\ (mm)^{2.546}$$

Weights at length for spiny lobsters (identified as Palinuridae, Palinuroidea, and *Panulirus* sp.) were calculated using the growth model developed for production foregone, as described in French McCay et al. (2015b).

As performed for the SEAMAP Ichthyoplankton survey (Section 7.1.1.4), fish abundances below 200 m (deep 1-m^2 MOCNESS) were apportioned to larval and juvenile estimates (Appendix C). Only larval abundances were reported and used for injury quantification. Ichthyoplankton daily ages were calculated as described in Section 7.1.1.5. Modal ages and percentages of abundance at the modal age were also calculated, as performed for the SEAMAP Ichthyoplankton, using age-frequency data derived from length-frequency measurements (Appendix D). The abundances of the decapod taxa were not broken out by stage, nor were modal ages calculated.

7.4 SEAMAP Shrimp/Groundfish Survey

Data used from the SEAMAP Shrimp/Groundfish Survey were downloaded from the Gulf States Marine Fisheries Commission (GSMFC) website (http://seamap.gsmfc.org/) on 6 March 2014. Samples collected from 1999 to 2009 were analyzed and split into spring (April, May, June) and summer (July, August, September) databases. It should be noted that the spring surveys predominantly included samples taken in June. Unlike the plankton surveys, samples were collected only within the 200-m bathymetric contour. The geographic range of trawls used was for an assessment region north of 27ºN and between 92ºW and 87ºW (Figure 7-5). Only the 40-ft long trawls with a mesh size of 1.63 inches (4.14 cm) were included, as this is the standard for the SEAMAP Shrimp/Groundfish Survey. As a result of these data filters, 1,441 samples were used in our analyses (Table 7-6).

Table 7-6. Number of samples in each of the subsets constructed from the SEAMAP Shrimp/Groundfish Survey.

Aggregation of SEAMAP Shrimp/Groundfish Data	Number of Samples in Dataset
Spring Inshore	616
Summer Inshore	825

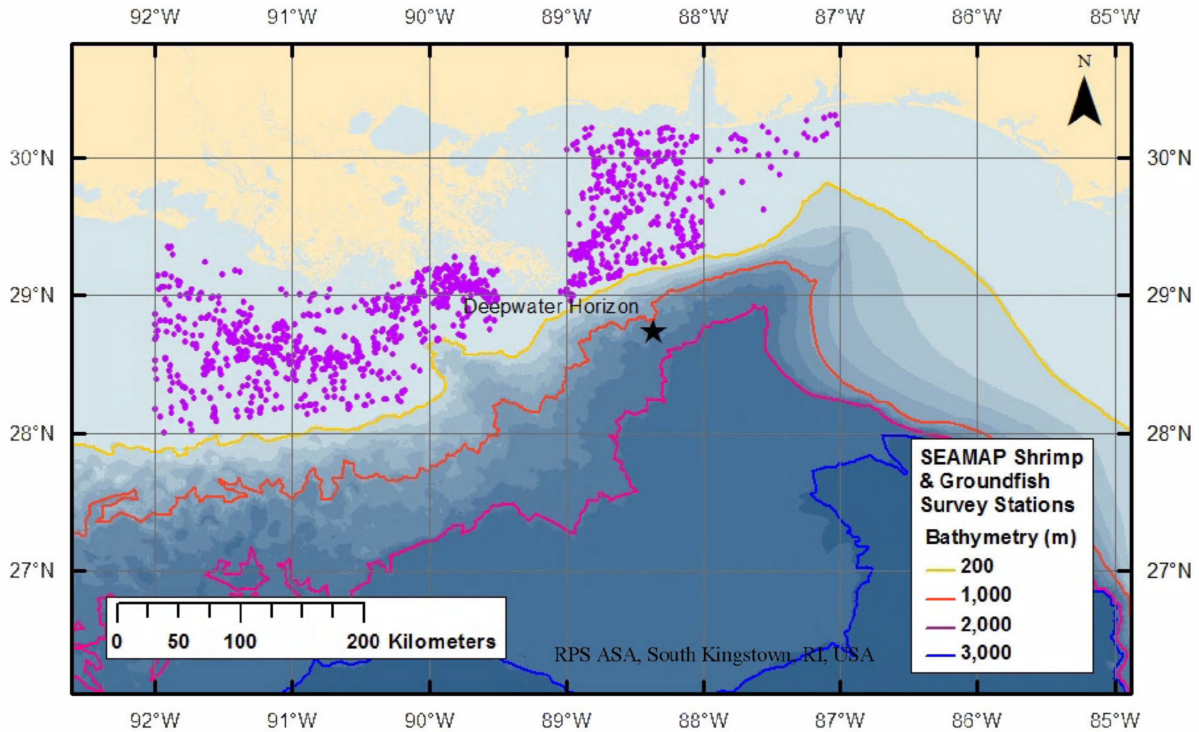

Figure 7-5. Geographic extent and survey station locations of SEAMAP Shrimp/Groundfish survey data used to derive juvenile and adult fish and invertebrate biomass estimates.

7.4.1 Data Processing

Distance fished for each SEAMAP Shrimp/Groundfish trawl was calculated using the start and end locations and accounting for the curvature of the Earth (D_C, nm):

$$D_C = R_E * arccos\big(\sin(Lat_S) * \sin(Lat_E) + (\cos(Lat_S) * \cos(Lat_E) * \cos(Long_S - Long_E))\big)$$

where R_E is the radius of the earth (set as 6,378.7 kilometers, or 3,437.7 nautical miles), *arccosine*, *sin* and *cos* are trigonometric functions, Lat_S and $Long_S$ refer to trawl staring coordinates and Lat_E and $Long_S$ indicate trawl ending locations. Before CPUE calculations, coordinates were converted from decimal degrees to radians. When calculating area fished, a net opening of 30 ft (9.144 m) was used based on recommendation from Butch Pellegrin (NMFS SEFSC Pascagoula Laboratory). The area the tow covered (km^2) was then calculated as the distance of the tow multiplied by the width of the mouth of the net.

The CPUE as biomass (kg km^{-2}) of organisms from each sample was calculated as:

$$CPUE = \frac{Biomass\ (kg)}{Area\ (km^2)}$$

For methods used for the calculation of seasonal mean CPUE and percentile confidence limits for the Shrimp/Groundfish survey datasets, please see Section 6.2.

7.4.2 Taxonomic Classification

Taxa were analyzed at the level of identification assigned by the field samplers. However, many of the names were misspelled or obsolete. Names were updated by creating a taxonomic relational table built to link correct names to those listed in the database. Correct taxonomies were confirmed by referring to the Integrated Taxonomic Information System (http://www.itis.gov/). Select species were excluded from the analyses because they were neither marine fish nor invertebrates (e.g., reptiles). Unidentified taxa were grouped together based on the available descriptions.

7.4.3 Length and Age Analyses

Length measurements were used for fish species where growth models were available (see French McCay et al. 2015b) to infer the size and age composition of the SEAMAP Shrimp/Groundfish catches. Length data used were from the same time period as was used for CPUE calculations (1999-2009) on the shelf (≥ 27°N) and separated into spring and summer datasets. However, the longitudinal region was extended to cover all of the Gulf States (≤-81.5°E) and increase the sample size. Length frequency distributions were tabulated from length measurements (nearest whole mm). Data outside of the 95% range (smaller or larger than the 2.5 and 97.5th percentiles, respectively) for each taxon were removed to exclude suspect data from analyses (methodology suggested by David Hanikso, NMFS SEFSC).

Length measurements were converted to ages based on the growth models used in production foregone calculations. Briefly, von Bertalanffy growth models from published literature were assigned to the fish species being analyzed to convert lengths to ages. Because the models are only appropriate for lengths equivalent to or greater than 1 year old, lengths shorter than this threshold were converted to daily ages using the first year of life model (see French McCay et al. 2015b). Daily ages were rounded down to the nearest whole day.

The SEAMAP program measured fish lengths as standard, fork or total length (SL, FL, TL). If needed, prior to age estimates, the length measurements were converted to the length measurement type used for the von Bertalanffy model construction. Length conversions were based on caudal fin type, with fin type assigned to taxa based on Barton (2007) classification (Table 7-7).

Table 7-7. Coefficients used to convert between length measurement types, based on caudal fin type. The regression model was linear: *New Measurement = m*Original Measurement + b*. Regression coefficients were derived from Fishbase for exemplar species caught in the Shrimp/Groundfish Trawl survey. Dashes indicate conversions that were not found or were not needed for our analyses.

Caudal Fin Type	TL to FL		TL to SL		FL to TL		FL to SL		SL to TL		SL to FL	
	b	m	b	m	b	m	b	m	b	m	b	m
Rounded	0	1	0	0.82	0	1	0	0.82	0	1.18	0	1.18
Truncate	0	1	0	0.82	0	1	0	0.82	1.056	1.154	1.056	1.154
Emarginated	0	0.95	0	0.8	0	1.05	0	0.83	0	1.2	13.2	1.15
Forked	0	0.87	0	0.8	0	1.13	0	0.9	0	1.2	0	1.1
Lunate	0	0.85	0	0.73	0	1.15	-0.56	0.96	0	1.27	0.67	1.03

Caudal Fin Type	TL to FL		TL to SL		FL to TL		FL to SL		SL to TL		SL to FL	
	b	m	b	m	b	m	b	m	b	m	b	m
Herterocercal	0	0.82	0	0.74	0	1.18	-	-	0	1.26	-	-
Homocercal	0	1	0	0.93	0	1	0	0.93	0	1.07	0	1.07

Median lengths for the juveniles in the samples (less than one year old) were calculated for all fish species with a juvenile stage represented in the SEAMAP samples. Species' proportions at each age (annual age classes, "juveniles" being the age 0 class) were calculated as the percent of age counts for each annual age group. All counts were rounded down to the whole age for percent calculations. The total mean, 2.5, and 97.5 percentile fish CPUE (as calculated in 7.5.1) were apportioned to age-specific estimates using the age classes' proportions.

While invertebrate CPUE were not broken out by age class, median lengths for the entire population caught were calculated for select invertebrates (Table 7-8).

Table 7-8. Median seasonal length measurements (mm, CL) used for select invertebrates collected in the SEAMAP Shrimp/Groundfish Trawl Survey.

Species (mm)	Spring (mm)	Summer (mm)
Farfantepenaeus duorarum	128	134
Farfantepenaeus aztecus	124	123
Litopenaeus setiferus	173	166
Callinectes sapidus	152	136
Callinectes similis	52	57

7.4.4 Catchability Correction

Taxa were classified by vertical distribution behavior, i.e., benthic, assumed to remain close to the sea bottom; demersal, assumed to remain near the bottom but not as tightly as the benthic taxa; and pelagic or planktonic, assumed distributed throughout the entire water column.

A number of different catchability methodologies were used to correct the SEAMAP Shrimp/Groundfish Survey CPUE. Catchability was first evaluated based on organism's behavior (q_B). For pelagic fish, a mean q_B value of 0.56 was used based on gear comparisons by Minello et al. (1991) for anchovies and Edwards (1968) for Atlantic butterfish and alewife. For demersal fish, such as flounders and those species that generally remain within 1 m of the seafloor, a q_B value of 0.1 was used based on gear comparison described in Somerton et al. (2007). For demersal fish that were assumed to remain within 10 m of the seafloor, a mean q_B value of 0.39 was used, which is based on general gear comparisons and stock assessment versus trawl-area-fished comparisons from Edwards (1968) for fourspot flounder, silver hake, red hake, little skate, goosefish and spiny dogfish, as well as estimates from mark-recapture compared with trawl-area-fished studies for Atlantic croaker, spot and pinfish (Loesch et al. 1976; Kjelson and Johnson 1978). These mark-recapture studies estimated a closed/semi-closed population size and then compared the estimated population size with the raw survey gear area-fished estimates to derive q_B. For demersal invertebrates, a mean q_B value of 0.45 was used derived from a mark-recapture versus a trawl-area-fished study (Loesch et al. 1976, for brown shrimp) and direct observations of fish/invertebrate behavior (Biron et al. 2007, for snow crab).

In order to validate the q_B estimates that were used to correct the SEAMAP Shrimp/Groundfish Survey CPUE, specific stock assessments were reviewed. Brodziak et al. (2007) and Harley and Myers (2001) applied a Bayesian framework to examine the relationship between survey catch (i.e., observed biomass) and stock-assessed biomass (i.e., true biomass), hence estimating q. The stock-assessed biomass may be estimated from catch-at-age type models, such as age-structured VPAs, which may combine survey catch data with fishery information, such as catch and age-specific mortality. In addition to providing a meta-analysis using this approach, Harley et al. (2001) analyzed stock assessments as compared to trawl area fished for demersal fish such as flounders and those species caught 1 m above the slope seafloor and estimated a q of 0.108. This estimate compares well with the q value of 0.1 that was used to correct the SEAMAP Shrimp/Groundfish Survey data based on Somerton et al. (2007). Additionally, RPS ASA did a comparison of assessment and raw-area-fished survey data for Gulf menhaden (Appendix B) and derived a q of 0.22 for pelagic fish, somewhat lower than the q value of 0.56 used based on Minello et al. (1991) and Edwards (1968). Fish and invertebrate species observed in the Shrimp Trawl were then assigned one of the q_B values based on behavior.

The q_B values were then used to further estimate catchability by accounting for organisms' vertical range in the water column (q_v). Benthic fish and invertebrate q_v values were set to 1.0, indicating the net adequately sampled their habitat. Demersal fish and invertebrates were assumed to move up to 10 m off the seafloor; thus their q_v values were calculated as their vertical distance off the bottom (10 m) divided by the height of the net. The height of the net was set to 0.89 m (Butch Pellegrin, NMFS SEFSC Pascagoula Laboratory). For pelagic fish and invertebrates, q_v for vertical availability was calculated as the mean water depth for all trawls (64.2 m) divided by the trawl height sampled (0.89 m), i.e., 72.14. The final catchability scheme coefficient was calculated by multiplying the behavior and vertical availability components ($q_B \times q_v$) (Appendix D). Final catchability coefficients were taxa specific.

7.5 NRDA 10-Meter^2 MOCNESS Survey

7.5.1 Data Processing

NRDA 10-m^2 MOCNESS (Multiple Opening and Closing Net and Environmental Sensing System) samples were used to quantity marine fish nekton abundances and planktonic invertebrate biomass integrated to a depth of 1,500 m. In each deployment, samples are taken over discrete depths using a frame with several nets attached. The first net opens on the downward cast, with subsequent samples taken at discrete depth intervals with the opening and closing of the other nets on the frame during the upward cast. Downward cast nets covering the water column were not provided in this database. Samples were analyzed from the Meg Skansi Cruise 7 conducted during April, May and June (Figure 7-6; French McCay et al. 2011d).

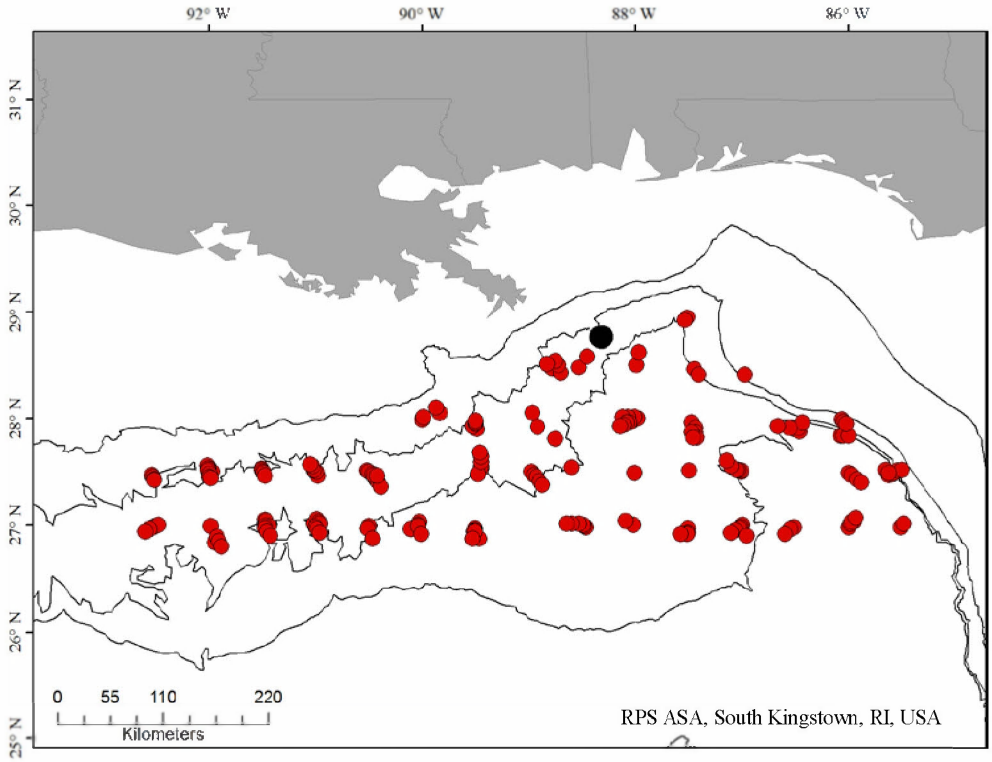

Figure 7-6. Locations of samples used from the NRDA 10-m^2 MOCNESS surveys, cruise MS7. MC252 Wellhead indicated with the black dot. Black lines represent 200 m, 1,000 m, 2,000 m and 3,000 m bathymetric contours.

In the version of the database used for this assessment (March 2014), several nets (i.e., samples) did not have accompanying volumes, thus were excluded from calculations. There were 66 deployments (stations), with at least one net having an accompanying volume, included in this analysis. For each net, $CPUE_v$ of a taxon was first calculated in terms of number (fish) or weight (invertebrates) per volume filtered. Next, treating each net as an estimate of the full-water column abundance or biomass since some nets were missing from the analysis (due to missing volume filtered data), that volumetric $CPUE_v$ was converted to a vertically-integrated estimate of abundance or biomass, i.e., # km^{-2} or kg km^{-2}, as follows, depending on whether it was a fish, decapods, or other invertebrate:

$$Fish\ and\ Decapod\ CPUE\colon \frac{Number}{km^2} = \frac{number\ caught}{volume\ filtered}\ x\ Z_D\ x\ 10^6$$

$$Other\ Invertebrate\ CPUE\colon \frac{Kilogram}{km^2} = \frac{(\frac{grams\ caught}{1000})}{volume\ filtered}\ x\ Z_D\ x\ 10^6$$

Volume filtered was reported in units of m^3, and Z_D represents the depth range of the MOC 10-m^2 deployment at the station sampled, which often times was the same as the water column depth. Multiplying samples' catch by the water column depth (and not the depth range sampled by the individual nets) allowed for water column integrated abundance and biomass estimates. This calculation assumes the catch from the samples is homogenous over the water column. However, when there was more than one net available per deployment, these calculations often times resulted in multiple integrated water column abundance and biomass estimates per deployment for a given taxa. Thus, integrated abundances were averaged over their respective deployment and taxa to obtain single abundance and biomass estimates for the entire water column at each deployment. This was done to avoid including zeros for nets that did not have a volume filtered. Analysis taxa were constructed based on taxonomy.

7.5.2 Taxonomic Grouping

Unidentified or order level taxa were categorized as they were identified by the laboratories. Species and genera were grouped to the family level, unless the given species or genera was also found in one of the other datasets being analyzed for injury assessment (e.g., NRDA Plankton Survey, NRDA Pisces Midwater Trawl).

After grouping to the analysis taxa level, CPUE of taxa within an analysis taxon were summed. Bootstrapping analysis was performed for the analysis taxa over the 66 deployment IDs to obtain confidence limits, as described in Section 6.2.

7.5.3 Length Calculations

Length measurements of fish were used to determine the portion of the CPUE that was larvae or juvenile/adult (nektonic, similar to the methods described in Section 7.1.1.4). All samples (with and without volumes) were used in the calculations because volume filtered was not required for this analysis. However, if there were taxa in nets without volume filtered measurements that were not found in the nets with volume filtered records, they were excluded from the data processing because they were not incorporated into the analysis taxa grouping scheme.

The proportion of abundance considered nektonic (termed as “juvenile or adult”) was calculated for each fish analysis taxa as the percent of length measurements greater than 23 mm, the assumed maximum size for larvae. This proportion was then multiplied by the total abundance for the taxa to produce juvenile/adult abundances. If the proportion was 0, the resulting fish abundance was also 0, and thus not reported in the final results (thus, Appendix D only reflects fish taxa with a portion of their overall abundance as juveniles and adults greater than 0). Median lengths for the juvenile/adult abundances were calculated using the length measurements greater than 23 mm. Median (50^{th} percentile) lengths were implemented as the length per individual.

For fish species with available growth and production foregone models (French McCay et al. 2015b), weight per individual was calculated using the median length and taxa’s weight-length relationship (see French McCay et al. 2015b). Juvenile and adult fish abundances (# km^{-2}), lengths (mm total length), individual weight estimates, and biomass (kg km^{-2}) for these species are tabulated in Appendix D.

Invertebrates were not apportioned based on life stage and the only total biomass was analyzed. For invertebrates, weight per individual was calculated for each sample by dividing the total of the taxon’s biomass by the number caught. The average weight per individual for each taxon was used to convert between weights and numbers per area. Invertebrate biomass (kg km^{-2}), individual weight estimates calculated from measured weight of all individuals in the taxon, and abundance (# km^{-2}) are tabulated in Appendix D.

7.6 NRDA Pisces Midwater Trawl

Nekton biomass based on NRDA Pisces Midwater Trawl data utilized the surveys conducted in June-July 2011 (*Pisces 10*), and September 2011 (*Pisces 12*) (French McCay et al. 2011b,e). Samples were collected at several sites offshore (Figure 7-7) during the day and night at both shallow (0-700 m) and full (0-1,400 m) depths. The full Pisces dataset consisted of 168 unique samples, which were collected during four Pisces cruises: numbers 8, 9, 10 and 12 (see Section 5.2.1). However, cruises 8 and 9 were not included in the analyses herein because the nets used in these cruises were different than the Irish Herring Trawl used in cruises 10 and 12; thus, the effective mouth areas (EMAs) were different enough that the catches were considered to be non-comparable. Thus, only 98 samples cruises 10 and 11 were used for CPUE calculations. Refer to Appendix D for a complete list of the analysis taxa used to calculate biomass from the NRDA Pisces Midwater Trawl Survey.

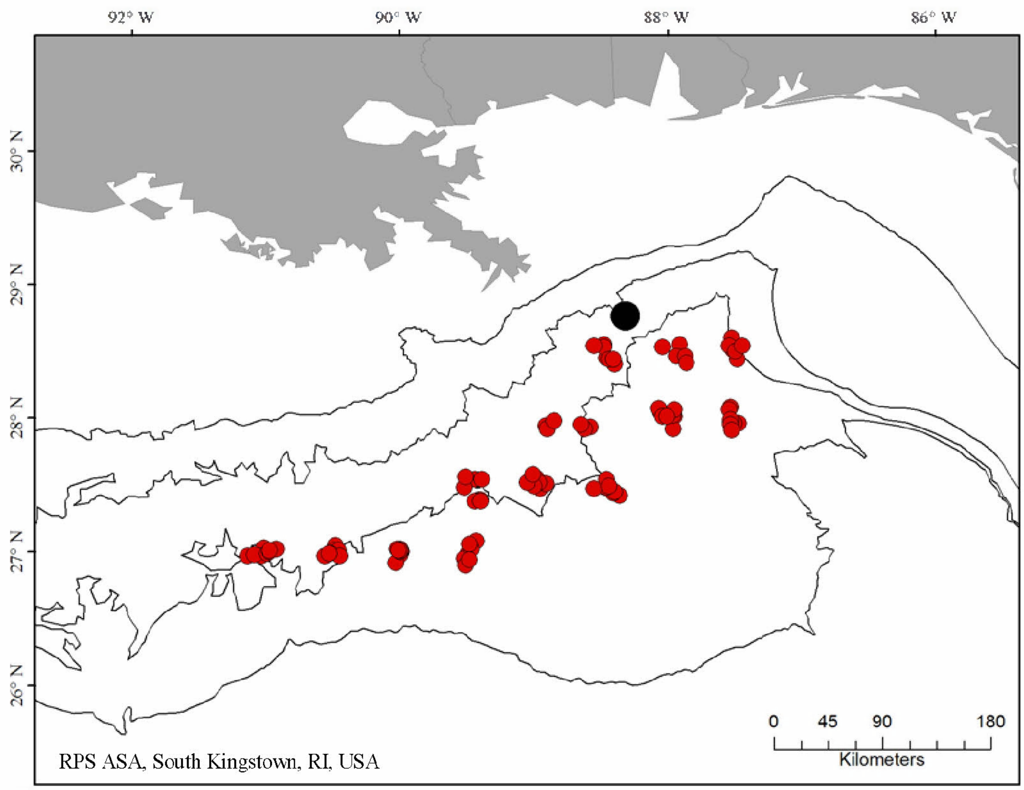

Figure 7-7. Locations of NRDA Pisces Midwater Trawl Samples (red) used in analyses. Only samples from cruises 10 and 12 were included in analyses. MC252 Wellhead indicated with the black dot. Black lines represent 200 m, 1,000 m, 2,000 m and 3,000 m bathymetry contours.

7.6.1 Data Processing

Organisms were analyzed at the taxonomic level described by the identification laboratories. CPUE as biomass (kg km^{-2}) was calculated as:

$$CPUE = \frac{biomass}{volume\ filtered}\ x\ Z\ x\ 10^{6}$$

where Z (m) represents the depth of the deployment, and biomass and volume filtered are in units of kg and m^3, respectively. Average CPUE and percentile confidence limits were calculated as described in Section 6.2.

Organisms' weights per individual were calculated for each sample separately, by averaging the total biomass divided by the number of individuals. A mean weight per individual was taken for each taxa over all of the surveys. Biomass (kg km^{-2}), individual weight estimates calculated from measured weight of all individuals in the taxon, and abundance (# km^{-2}) are tabulated in Appendix D.

7.7 NRDA Flying Fish Observations

7.7.1 Data Processing

From 8 July 2011 through 14 July 2011 during the McArthur II Bongo-Neuston Survey, visual counts of flying fish observed jumping from the water were made from the bridge wings. A total of 148 segments (approximately 10 minutes long each) of visual counts were collected (Figure 7-8).

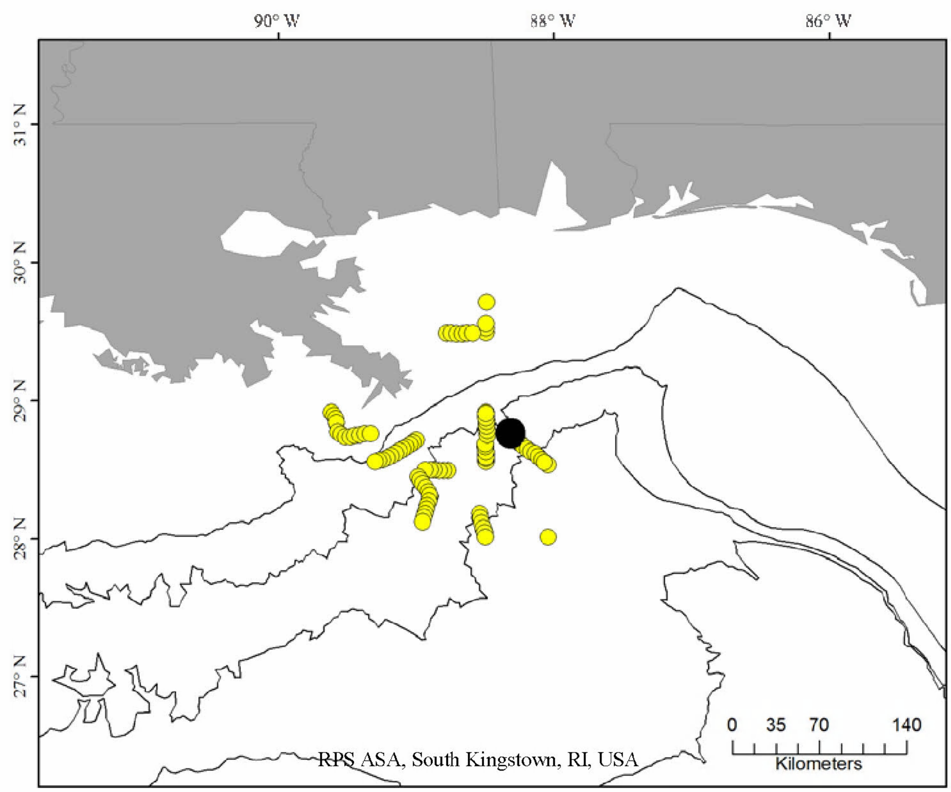

Figure 7-8. Locations of NRDA Visual Flying Fish Observation transects (yellow). MC252 Wellhead indicated with the black dot. Black lines represent 200 m, 1,000 m, 2,000 m and 3,000 m bathymetric contours.

The majority of these segments were paired port/starboard observations. Five of the segments were excluded from the analysis because the latitude/longitude coordinates, as recorded, appeared to be incorrect and the distance traveled by the ship during those segments was not possible to calculate. All flying fish observed were classified as “flying fish” (common name) or “Exocoetidae” (Family Latin name). Area sampled during transects (km^2) was calculated as:

$$Area = ((Lat_S - Lat_E)^2 + (Long_S - Long_E)^2)^{1/2}\, x\, 60 \min x\, 1{,}852\, m\, x\, 50m\, x\, 10^6$$

The start and end latitude and longitudes were used to determine the distance traveled by the boat (using the Pythagorean Theorem). The inputs of 60 min and 1,852 m were used to convert from decimal degrees to meters. The effective viewing distance for flying fish from the boat was set to 50 m. This distance was assigned after considering the observers’ height above sea level, the speed of the boat, the conditions during observations and the minimum distance required to startle flying fish due to boat activity (perceived by fish as a predator) and thus leave the water (Zuyev and Nikol’skiy 1980). The abundance of flying fish was then calculated as the number observed divided by the area covered (# km^{-2}). Mean abundance and percentile confidence limits were calculated as outlined in Section 6.2.

7.7.2 Catchability Correction

Flying fish abundances were corrected to roughly account for individuals that were not visually observed and below the surface. Zuyev and Nikol’skiy (1980) indicated that roughly 20% of the fish are in the observation zone (i.e., “flying”). Thus, a catchability scalar of 0.2 was applied to the abundances.

7.8 Deep Gulf of Mexico Benthos Survey (DGoMB)

7.8.1 Fish (Powell et al. 2003)

7.8.1.1 Data Processing

Mesopelagic demersal fish biomass was estimated from the Deep Gulf of Mexico Benthos survey program (Rowe and Kennicutt II 2009) as summarized by Powell et al. (2003). This was a deepwater trawl study from depths of 200 m to greater than 3000 m. Powell et al. (2003) used a 40-foot semi-balloon otter trawl along transects down the continental slope (shallow to deep) at numerous sites in the Northern Gulf of Mexico, 1 tow per station (Figure 7-9). Taxa that were considered pelagic were removed from our analysis because they were ineffectively sampled by the semi-balloon trawl and covered by other surveys analyzed. Refer to Appendix D for the list of the analysis taxa used to calculate biomass from the DGoMB.

Raw data from the DGoMB trawl survey (Powell et al. 2003) were directly provided by Richard Haedrich, a co-principle investigator on the project. The raw data consisted of number of individuals caught and displacement volume of each species/taxon for each tow. To convert displacement volume into the total weight of species/taxon per tow, volume displaced as milliliters was converted to cubic meters and was then multiplied by 1,030 kg/m^3, or the density of seawater, assumed to be the same as the density of fish tissue (Serway et al. 2000). Weight per individual (kg) was then calculated by dividing the total weight (kg) of the species/taxon by the number of individuals caught in the tow.

Area swept for each tow was calculated by multiplying the distance trawled (which was tow-specific) by the assumed wingspread of the net (10 m). To calculate biomass (kg km^{-2}), the total weight of the species/taxon in each tow was divided by the area swept. Analysis taxa groups were based on the lowest level of identification provided in the raw data list, resulting in 136 different analysis taxa. Mean biomass and percentile confidence limits for the DGoMB dataset were calculated as described in Section 6.2 and are reported in Appendix D.

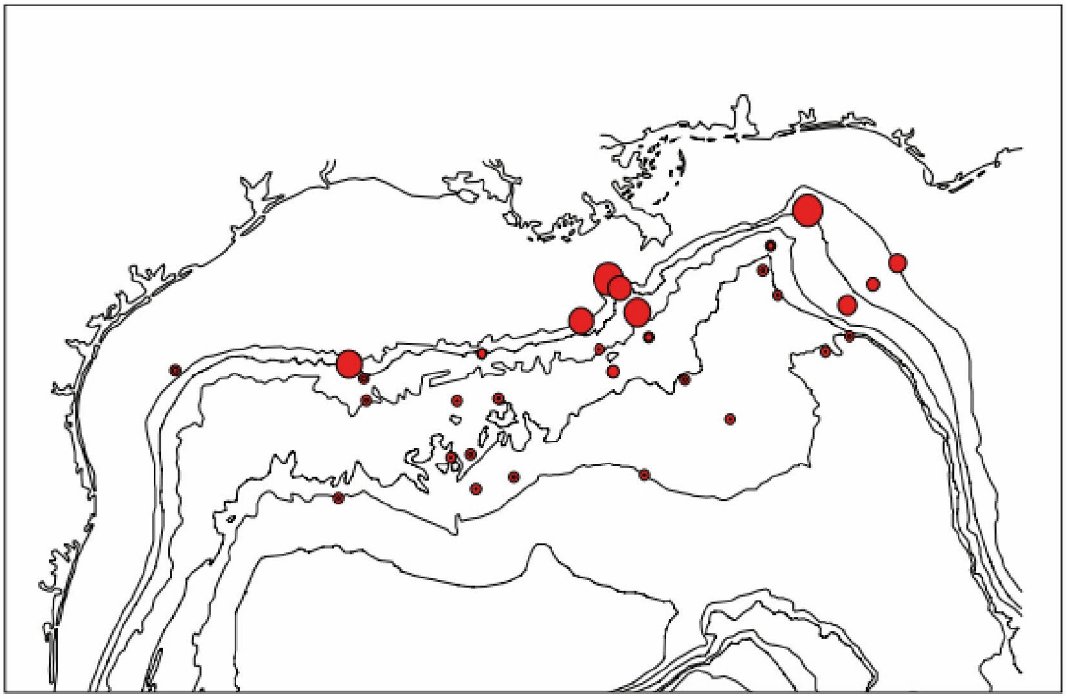

Figure 7-9. Abundance of fish at each DGoMB station scaled as the log of the number/hr. The largest dot is equivalent to a CPUE of 290 fish/hr. The remaining dots are scaled appropriately. Source: Powell et al. (2003).

7.8.1.2 **Catchability Correction**

The 40 foot semi-balloon trawl likely sampled up to 10m above the seafloor (Powell et al. 2003). Because the trawl caught primarily taxa associated with the seabed, it was assumed that a high percentage of the typical habitat for demersal and semi-demersal taxa was effectively sampled, and was highly available to the gear type. Therefore, biomass estimates were uncorrected for a vertical availability component of catchability.

Catchability values regarding gear type were mined from the literature and applied to the biomass data (Appendix D). The q values only reflect vulnerability to the gear, since demersal species were assumed not to occur above the reach of the net. Catchabilities were applied at a family level, where all taxonomic groups within that family were assigned the same q value.

For strictly demersal fish species, q values from published studies (Edwards 1968; Somerton et al. 2007; Kjelson and Johnson 1978; Harley et al. 2001; Brodziak et al. 2007) that had similar species/gear types as the DGoMB Survey were applied. Similarly, for semi-demersal fish species, q values from Edwards (1968) for similar species/gear types as the DGoMB were applied. These q values represent the vulnerability aspect of catchability (Edwards 1968), Given that pelagic species were removed, there was no vertical catchability component applied to the taxa analyzed.

7.8.2 Invertebrate Megafauna

7.8.2.1 Data Processing

Invertebrate megafauna abundance and biomass was quantified during the DGoMB Study from 2000-2002 (Rowe and Kennicutt II 2009). Invertebrate megafauna were observed using seafloor photography. During the DGoMB surveys, 1,421 images were taken at 45 sites to analyze megafauna abundance, with each image covering 2 m^2 of the sea floor. Only animals readily identifiable in each image were counted. Figure 7-10 shows the total “densities” as number per hectare from the survey, as provided by Rowe and Kennicutt II (2009).

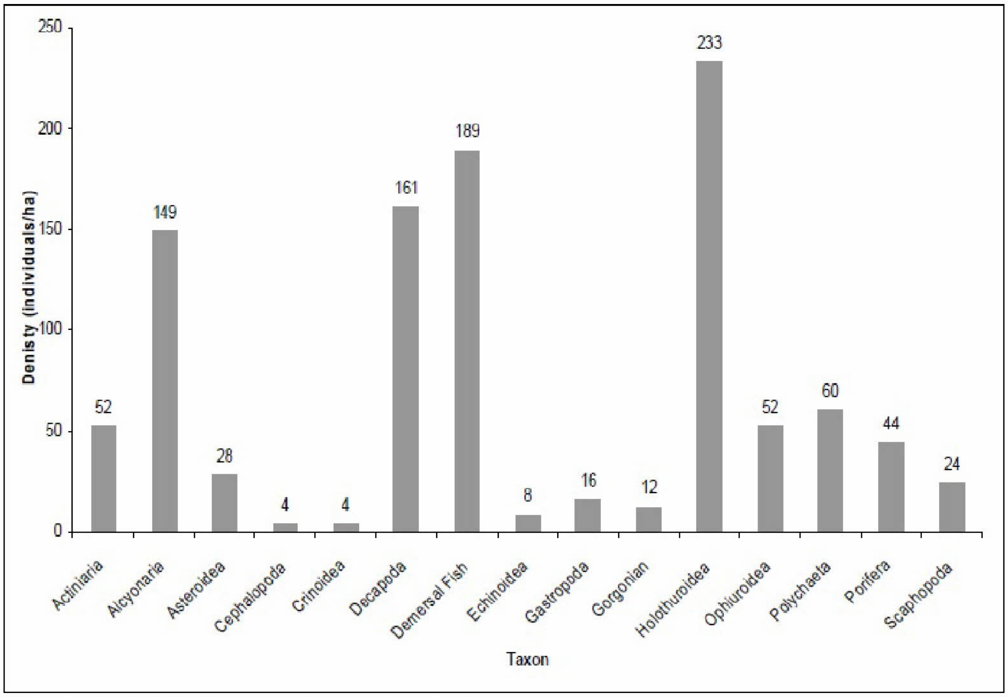

Figure 8-154. DGoMB total megafaunal density (individuals/ha) by taxon.

Figure 7-10. Total densities (i.e., numerical abundance per unit area) of megafauna from the DGoMB by analysis taxon (from Rowe and Kennicutt II 2009). Bar values are located above bars directly. Demersal fish from the video surveys were excluded because this group was assessed using data from the Powell et al. (2003) study.

Average abundance for each taxa (# km^{-2}) were calculated as:

$$Abundance = \frac{\#}{ha}\ x\ \frac{1\ ha}{0.01\ km^2}\ x\ \frac{1}{45\ sites}$$

Variance for the invertebrate megafauna counts were not provided within the report. To determine confidence limits, the standard deviations were first calculated as half of the final mean abundance, assuming the variances in observed counts per hectare were normally distributed. Then, ~2.5 and 97.5th percentiles were calculated as ± 2SD's. Grams per individual were derived from the NRDA MOC10 sampling. Average g/individual was calculated by phylum, and assigned to taxa of the DGoMB in the same phylum. For taxa from the DGoMB survey without their phylum represented by taxa in the 10-m^2 MOCNESS dataset, an average of all taxa from the 10-m^2 MOCNESS sampling was used for converting counts to biomass.

7.9 Stock Assessment-Based Estimates

Abundances and biomass of certain fish species were based on information from stock assessments (ICCAT and SEDAR), as these are well-studied species and the stock assessment provides estimates of total fish in the Gulf of Mexico. The surveys and gear types explained previously do not effectively sample these species as adults. Each stock assessment provides the total stock biomass (by year, sometimes by age), a portion of which is assigned to the Gulf of Mexico (for stocks reaching beyond the GOM), and then distributed across its likely habitat to estimate the biomass per unit area. The average of stock biomass over the most recent 5 years prior to 2010 was used. Biomass was in metric tons (mt), and converted to kg km^{-2} by using an area of 949,768 km^2 for the Gulf of Mexico (except for sailfish and gulf menhaden which occupy 435,182 km^2, the area within the 200-m depth contour) and proportion factors, used to estimate their area coverage within the Gulf and not the broader range covered in the ICCAT or SEDAR report (ranging from 0.01-1 depending on the species).

All stock assessed species were assigned biomasses of kg km^{-2} based on arithmetic means of the most recent 5 years of biomass data available. This ranged from 2001-2005 for skipjack tuna to 2005-2009 for several species. The five years of biomass values used to compute the arithmetic mean were used as inputs for the bootstrapping calculations. Bootstrapping for developing percentile-based confidence limits were performed using the approach described in Section 6.2.

Abundance calculations in # km^{-2} were calculated from kg km^{-2} by assuming the majority of individuals were of the age one year class (except for Atlantic bluefin tuna, which were assumed to be age 8 years, the youngest >age-1 year age class present in the Gulf of Mexico) and using the life table produced as described in the production foregone report (French McCay et al. 2015b) to determine kg per individual at that age class.

7.10 Nearshore Louisiana Trawl Surveys – Brown et al. (2013)

In order to estimate biomass of juvenile fish and large invertebrates in the nearshore estuaries, data describing biomass and sizes of taxa in the nearshore environment were extracted from a study conducted by Brown et al. (2013). The goal of the study was to quantify the commercially significant species in Gulf of Mexico estuaries and assess the variability in species presence across estuaries. For our analyses, only data from Louisiana coastal waters were used to ensure data were obtained using consistent sampling methods and due to the greater length of the time series data available than for other states. The assessment region for this study included the Terrebonne-Timbalier Bays, Barataria Bay, and the Breton-Chandeleur Sounds (Figure 7-11).

Samples were collected from 1986-2007 using 4.9-m flat otter trawls. Monthly mean abundances and biomass (# and g/ha) for each LA region over the years were obtained from the report for each species. Seasonal abundance averages and percentile (2.5 and 97.5) confidence limits for the LA coastal waters were calculated with the bootstrapping technique (Section 6.2) for spring (April, May, June) and summer (July, August, September). Biomass was then converted from grams ha^{-1} to kg km^{-2}. Length information (mean with standard deviation) for the species was also extracted from the report to determine the average size of individuals from the sampling in the assessment region.

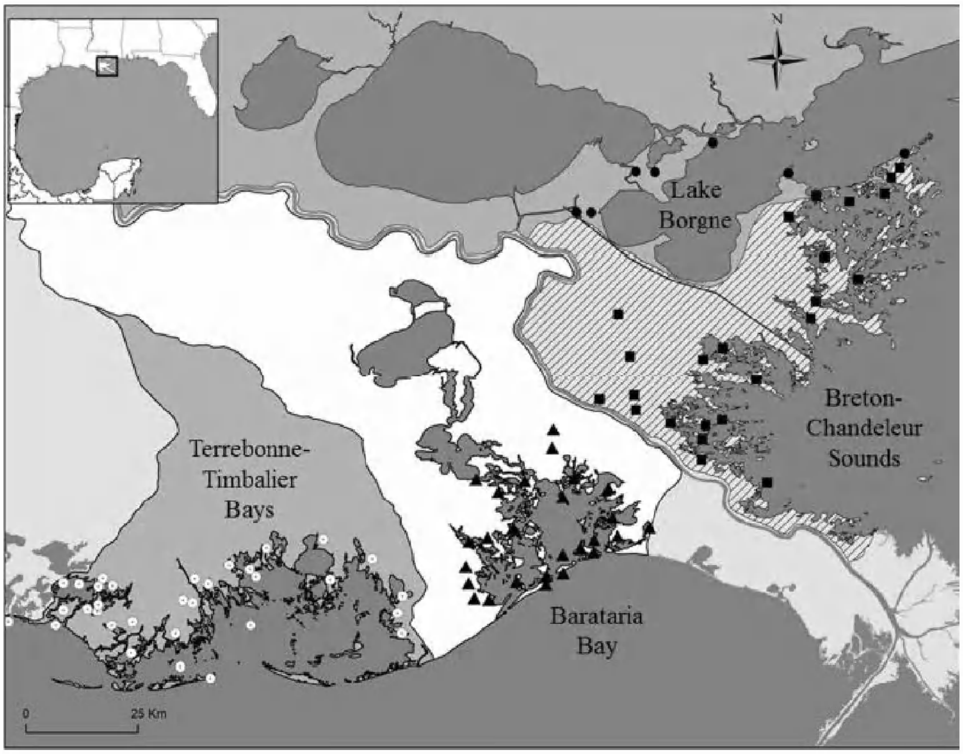

Figure 7-11. Study areas in Louisiana waters used for the Nearshore analysis. Lake Borgne region was not included in the analysis. Circles, triangles and squares represent trawling locations for the respective region. Source: Brown et al. (2013)

7.11 Nearshore Plankton Surveys – FOCAL Program

7.11.1 Ichthyoplankton

Data from the Dauphin Island Sea Laboratory's Fisheries Oceanography of Coastal Alabama (FOCAL) program were used to estimate lagoon and estuarine (hereafter jointly referred to as nearshore) ichthyoplankton densities and sizes (Dauphin Island Sea Lab 2009). The FOCAL database used for analyses was received on 19 July 2011 from Dr. Frank Hernandez. The program uses several different gear types, most notably a version of the Bedford Institute of Oceanography, Net Environmental Sampling System (BIONESS) system, referred to as "Mininess" (Hernandez et al. 2010; Carassou et al. 2011) The Mininess operates similarly as a MOCNESS frame, sampling over the water column both obliquely (downcast) and depth discretely (upcast).

For these analyses, samples were analyzed from 2007-2009 at the Mobile Bay and Dauphin Island stations to estimate near-shore ichthyoplankton abundances and sizes (Figure 7-12). Downcast Mininess samples were used because all of these nets were equipped with 333 µm, therefore providing standardized gear in comparison to the samples used in offshore analyses. All taxonomic names were reviewed and updated to correct spelling errors, inconsistent identifications within taxa, and implement recent taxonomy changes. Densities were calculated by sample using total count by taxon, total volume swept by the net, and aliquots; densities were expressed as number per cubic meter (# m^{-3}). The taxa's densities were calculated as means and bootstrapped 2.5% and 97.5% confidence intervals (as described in Section 6.2). Total densities were reported as monthly estimates for April through September (Appendix E).

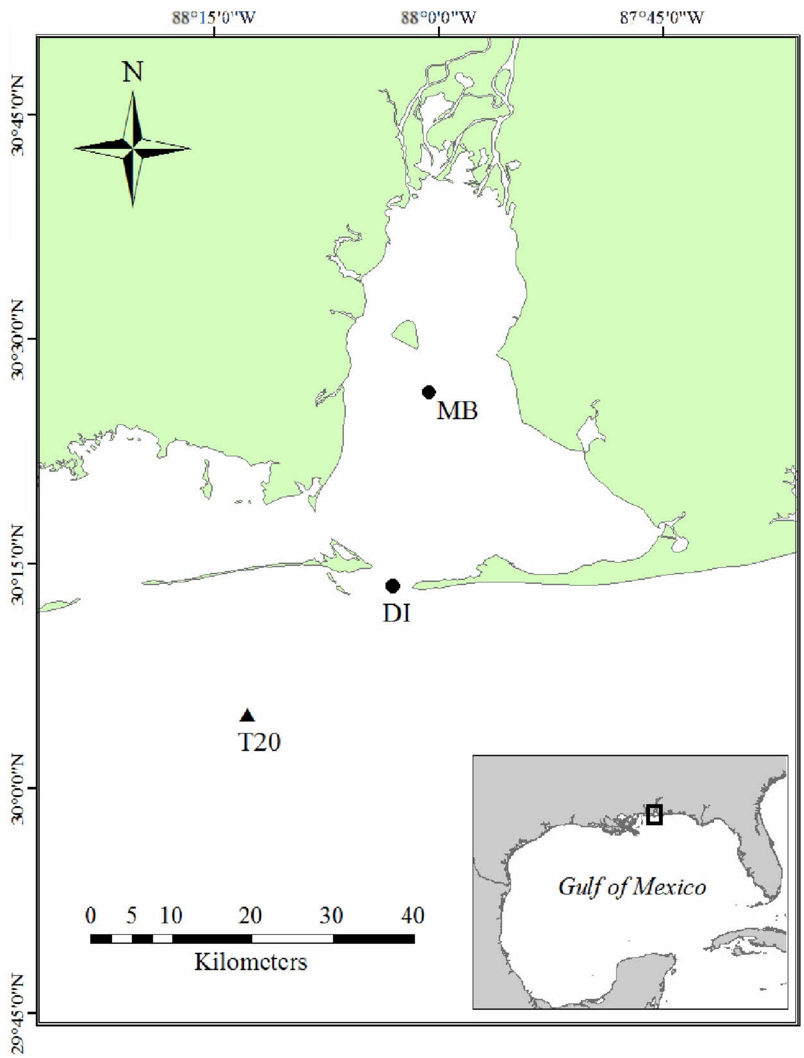

Figure 7-12. FOCAL stations in coastal Alabama waters. Samples from stations MB (Mobile Bay) and Dauphin Island (DI) were used in quantifying ichthyoplankton (circles) densities for the near-shore region, while invertebrate zooplankton densities used were from Station T20 (triangle), as described in Carassou et al. (2014).

Ichthyoplankton length measurements (mm) were analyzed to determine the size range and dominant size class represented. Length measurements were extracted for fish larvae for all of the corresponding samples used in the density calculations. However, length calculations were calculated across all months (April-September), representing the sizes of spring and summer combined. Modal lengths (using 0.1 mm increments) for each fish taxa were calculated based on length-frequency data. The fraction of the modal size class for the population was then calculated as the number of length counts of the modal size divided by the taxa's total number of length observations. Densities at the modal size class over months were then calculated by multiplying taxa's modal size fraction by their respective total densities in each month. The modal size densities, tabulated in Appendix E, are also in units of # m^{-3}.

Note that the FOCAL-based nearshore fish larval densities are based on modal size classes, as opposed to modal daily age classes as calculated for the SEAMAP and NRDA Below 200 m ichthyoplankton datasets described in Sections 7.1 and 7.3. Densities of ichthyoplankton based on the FOCAL data set are reported in Appendix E, as opposed to Appendix D, because they are volumetric as opposed to integrated over the water column or sampling depth range.

7.11.2 Invertebrate Zooplankton

FOCAL data were delivered to RPS ASA on July 19, 2011; however, samples quantifying invertebrate zooplankton at the time of delivery were incomplete, thus not suitable for quantifying near shore invertebrate zooplankton densities. Invertebrate zooplankton densities were derived from Carassou et al. (2014), which used FOCAL data that had been processed through the pre-spill period. Samples used for baseline densities were collected between May and August from 2005 through 2009 at Station T20, approximately 20 km south of Dauphin Island, using the BIONESS system. While this station is not located in estuarine waters, given its proximity to Mississippi and Alabama estuarine waters, data from this station were used to represent all near shore waters exposed to oil. Unlike analyses for the FOCAL ichthyoplankton, samples from this study were collected using a 0.202 mm mesh net. Average densities (# m^{-3}) with standard errors were reported for 24 major zooplankton taxa collected at T20. Densities of invertebrate zooplankton are tabulated in Appendix E

8 Summary of Biological Abundances and Size Distributions

8.1 Estimated Baseline Abundance and Biomass

The subsections below present a brief summary of the results calculated from each dataset. Note that when applicable, abundance and biomass are described with and without catchability corrections. For a complete list of all results and uncertainty ranges see Appendix D.

8.1.1 SEAMAP Ichthyoplankton Survey (Fish Larvae and Small Juvenile Fish)

Larval fish abundances were highest over the shelf (within the 200-m bathymetry contour) regardless of season, with the highest total ichthyoplankton abundance in the spring inshore region exceeding 313 million individuals km^{-2}. Fish eggs were the most abundant taxonomic group found in any seasons/geographic range, reaching a maximum of 157 million eggs km^{-2} in the spring/inshore region. Small mesopelagic fish, such as lanternfish, bristlemouths and hatchet fish, were typically the most abundant ichthyoplankton, particularly offshore. Mesopelagic taxa with the greatest abundances include Myctophidae (*Diaphus* sp., *Myctophum* sp., *Hygophum* sp., *Benthosema suborbitale*), Gonostomatidae and Bregmacerotidae. Abundances for these families were well over millions km^{-2}, with some in the tens of millions. In the inshore region, more coastal species were abundant, such as clupeids (Clupeiformes, Clupeidae), anchovies (Engraulidae), and Atlantic thread herring (*Opisthonema oglinum*). Other major inshore ichthyoplankton taxa include Atlantic bumper (*Chloroscombrus chrysurus*), seatrout (*Cynoscion* sp.) and flounders (e.g., *Syacium* sp., Bothidae, *Etropus* sp.). Swordfish (*Xiphias gladius*) was the least abundant taxa caught over all seasons and regions. Red snapper (*Lutjanus campechanus*) was most abundant in the summer within 200 m from shore at 165,523 larvae km^{-2}. Atlantic bluefin tuna (*Thunnus thynnus*) in the spring was more abundant in the offshore than inshore region (394,314 larvae km^{-2} compared to 256,252 larvae km^{-2}). King and Atlantic Spanish mackerel abundances (*Scomberomorus cavalla* and *Scomberomorus maculatus*, respectively) were found in all seasons/regions at abundances of tens to hundreds of thousands km^{-2}.

The SEAMAP ichthyoplankton catches were primarily comprised of true larvae (Appendix C). Roughly 89% and 94% of unique taxa in spring and summer respectively had 95% or more of individuals comprised of true larvae, with the remaining percentage being juveniles. True larvae comprised 99.3% of the total SEAMAP ichthyoplankton abundances. Many of the taxa with large portions of their abundances representing juveniles were eels or taxa with a leptocephalus stage (e.g., Muraenidae, Nettastomatidae, Congridae, Ophichthidae, Synaphobranchidae). This is due to the fact that older individuals were captured in the samples, possibly because of higher catchability at older ages than those taxa where only small individuals were caught. Ichthyoplankton median lengths by taxa were similar between spring and summer, ranging from 1.5-17 mm in the spring and 1.5-20.3 mm in the summer. Seasonal median lengths of the larvae of all taxa were similar, i.e., 3.4 mm and 3.1 mm in the spring and summer, respectively. Modal ages for the larval fish ranged from 1 to 25 days old, with half of the ichthyoplankton taxa having modal ages less than or equal to 4 days old.

Regressions and results for the ichthyoplankton generalized additive models (GAMs) can be found in Christman and Keller (2015). The GAM projections for the 10 prediction days provided by Christman and Keller (2015) highlight spatial and temporal variability for certain ichthyoplankton taxa. For example, GAM predictions indicate that menhaden (*Brevoortia* sp.) and Atlantic bumper (*Chloroscombrus chrysurus*) remain close to the Louisiana and Texas coastline, with the former taxa particularly abundant in the vicinity of the Mississippi River Plume. Other taxa strongly associate with the shelf (*Lutjanus campechanus, Scomberomorus cavalla*, Anguilliformes) or offshore waters (*Diaphus* sp., Gonostomatidae, *Thunnus* sp., *Thunnus thynnus, Coryphaena* sp.). Additionally, some taxa seem to be located primarily offshore, with high aggregations in the vicinity of the MC252 Wellhead (e.g., *Selar crumenophthalmus, Diaphus* sp., *Harengula* sp. in June 2010, Ophichthidae through spring and summer). Fish eggs had the highest mean abundance in the SEAMAP Ichthyoplankton surveys and were predicted to be generally most abundant nearshore with decreasing abundances in deeper waters. GAM predictions may be compared to the means of the abundances in the four subsets of the SEAMAP ichthyoplankton database trimmed to the assessment region (27-31ºN and 87-92ºW, Figure 7-1) and used to evaluate variability of the GAMs from the means in that region. Mean and GAM-predicted fish egg abundances and many larval taxa were within an order of magnitude of each other, with both varying based on season and region. However, in the assessment region used for the mean abundances, predicted abundances of eggs were not homogenous over space. Based on the GAM predictions, abundances of some larval taxa were also not homogeneous in the assessment region, whereas other species (including red-eye round herring [*Etrumeus teres*], Apogonidae, and menhaden [*Brevoortia* sp.]) did appear to be generally homogenous in space. (See maps in Christman and Keller 2015).

8.1.2 SEAMAP Invertebrate Zooplankton Survey

Invertebrate micro-zooplankton total biomass (excluding larval and planktonic decapods) was highest in the spring in waters offshore of the 200-m bathymetric contour (34,006 kg km^{-2}), but only slightly higher than that of the inshore waters in the summer (31,624 kg km^{-2}). Siphonophores were one of the taxa with the highest biomass over all seasons, reaching a maximum biomass of 19,464 kg km^{-2} in the spring offshore, the highest single biomass for any taxa. Other abundant taxa from the SEAMAP Invertebrate Zooplankton sampling include doliolids, chaetognaths, salps and calanoid copepods. With catchability coefficients applied, the previously mentioned invertebrate zooplankton taxa remain prominent in abundance. However, hydromedusae increased dramatically to one of the most abundant taxa in the dataset, reflecting the influence of incorporating the proportion lost to gear or behavior.

8.1.3 NRDA Plankton Surveys

In samples above 200m, *Lucifer* sp. was the most abundant decapod observed, exceeding 745 million individuals km^{-2}. Other major decapods found in the upper 200 m of the water column include miscellaneous Brachyuran crabs, Caridean shrimp, and Sergestid shrimp including the subspecies *Acetes americanus carolinae*. However, these four taxa were all roughly 6-22 times less abundant than *Lucifer* sp. Lobster larvae (Palinuridae and *Panulirus* sp.) were relatively low in abundance compared to other planktonic decapods from the NRDA (bongo) above 200-m samples. Median decapod length per individual ranged from 0.5-14.5 mm depending on the taxa. All but three taxa had median lengths less than 10 mm per individual.

Many of the fish taxa caught in the NRDA below 200m (by 1m^2 MOCNESS) were entirely, or nearly entirely, comprised of true larvae. However, the majority of viperfish (*Chauliodus* sp.) and bristlemouth (*Cyclothone* sp.) were juveniles (Appendix C). After correcting the abundances with the proportion of true larvae using correction coefficients (Appendix C), *Cyclothone* sp. was the most abundant of all larval fish or decapods caught in the NRDA Below 200-m samples at 4,685,084 fish km^{-2}. Myctophids (*Diaphus* sp., *Hygophum* sp., Myctophidae) and unidentified

Stomiiformes were also very abundant (although 2-3 times less abundant than *Cyclothone* sp.). Median larval fish and decapod size ranged from 1.6-17.1 mm, of which 18 of the 53 taxa's median lengths per individual were greater than 10mm. Modal ages for larval fish ranged from 1 to 26 days old; *Chauliodus* sp. had the oldest modal age of 26 days. Lobster larvae were not found below 200 m.

8.1.4 SEAMAP Shrimp/Groundfish Survey

Fish and invertebrate biomass, uncorrected for catchability, in the SEAMAP Shrimp/Groundfish Trawl survey totaled 1,904 kg km^{-2} in the spring and 1,728 kg km^{-2} in the summer. Regardless of season, most fish sampled by the gear were juveniles, followed by one and two year old fish. However, several species had many size classes caught (e.g., *Lutjanus griseus*, *L. synagris*), with the most diverse size composition being that of the sand devil, *Squatina dumeril* (with a broad range of sizes represented).

The species with the highest biomass caught in both seasons was red snapper (*Lutjanus campechanus*) at 539 and 733 kg km^{-2} in spring and summer, respectively. The other species caught in the spring, with biomass greater than 100 kg km^{-2}, include the longspine porgy (*Stenotomus caprinus*), gulf butterfish (*Peprilus burti*), and spot (*Leiostomus xanthurus*). The major invertebrate species caught in the spring were brown shrimp (*Farfantepenaeus aztecus*) and lesser blue crab (*Callinectes similis*) at 55 and 33 kg km^{-2}, respectively. The longfin inshore squid (*Loligo pealeii*) with the highest biomass was the squid species caught in the spring (14 kg km^{-2}). These same species were found in the greatest biomass in the summer months, at similar magnitudes. Only the Atlantic bumper (*Chloroscombrus chrysurus*; among the taxonomies with the highest biomass) was found in much greater biomass in summer than in spring with a biomass in the summer of 94 kg km^{-2} compared to 31 kg km^{-2} in the spring.

Application of the catchability corrections highlight the influence of accounting for pelagic species inadequately sampled by the demersal bottom trawl. With the catchability corrections applied, red snapper fell well outside the top ten most abundant species in spring and summer. The correction led to markedly higher numbers for pelagic species, with some of the more noticeable changes seen for longfin inshore squid, scaled sardine (*Harengula jaguana*), broad-striped anchovy (*Anchoa hepsetus*), and Atlantic cutlassfish (*Trichiurus lepturus*). Other taxa, such as Atlantic Spanish mackerel (*Scomberomorus maculatus*), that were very low in numbers without applying a catchability correction increased to moderate abundance.

8.1.5 NRDA Pisces Midwater Trawl

In the NRDA Pisces Midwater Trawl sampling, myctophids (Myctophidae) was the taxa with the highest biomass at 3,144 kg km^{-2}. *Cyclothone* sp., unidentified decapods (Decapoda), Elopomorpha, Cephalopoda, and Perciformes fish were the next most abundant taxa, although all were roughly 1.5-4 times less than that of myctophids. The species-specific taxon with the highest biomass was *Chauliodus sloani* (797 kg km^{-2}). Jacks (Carangidae) were caught in the midwater trawl, however at low biomass (21 kg km^{-2}). The scalloped ribbonfish (*Zu cristatus*) on average has the greatest weight per individual at 512 g.

8.1.6 NRDA Flying Fish Observations

Exocoetidae abundance observed from the NRDA flying fish program averaged 17 km^{-2}. Correcting for animals unaccounted for visually increased the abundance to 86 km^{-2}.

8.1.7 Gulf of Mexico Benthos Survey (DGoMB)

The DGoMB study caught primarily bathypelagic and bathydemersal species. Total biomass caught during the survey was 191 kg km^{-2}. Bullseye grenadier (*Bathygadus macrops*) and gulf hake (*Urophycis cirrata*) were the two species with the highest biomass from the DGoMB surveys at 46.5 and 21.0 kg km^{-2}, respectively. Other major fish caught in the survey include the thickbeard grenadier (*Coryphaenoides zaniophorus*), the Gadiforme *Laemonema goodebeanorum*, and the deepbody boarfish (*Antigonia capros*). After catchability corrections, the bullseye grenadier was still the taxa with the highest biomass; however, offshore silver hake (*Merluccius albidus*) was now the taxa with the second highest biomass in the survey. Even with catchability corrections, 81 of the 136 taxa were less than 1 kg km^{-2}.

Anthozoans (Alcyonaria) were the most abundant of the invertebrate megafauna as part of the DGoMB video survey. Sea anemones (Actinaria) and sea cucumbers (Holothuroidea) were also rather abundant in comparison to anthozoans. While this survey provides estimates for large deep sea invertebrates, the biomass estimates are likely underestimates, as the video survey only incorporated organisms easily identified and imaged the seafloor (thus free swimming organisms such as cephalopods may not have been captured well).

8.1.8 NRDA 10-Meter^2 MOCNESS Survey

Fish caught in the NRDA 10-m^2 MOCNESS survey were a mix of larvae and juveniles/adults. Juvenile/adult fish abundance totaled 3.2 x 10^6 km^{-2}. Mesopelagic fish including myctophids, lanternfish and bristlemouths were the most frequently caught fish in the survey. When evaluating the juvenile/adult population, winged lanternfish (*Lampanyctus alatus)* and bristlemouth (*Cyclothone* sp.) were the taxa with the highest abundance at 521,435 and 448,085 individuals km^{-2}, respectively.

Invertebrate biomass from the 10-m MOCNESS survey totaled 2,708 kg km^{-2}. Purple striped jellyfish (*Pelagia noctiluca)* was the invertebrate with most biomass at 267 kg km^{-2}. Pteropods (Pteropoda), and the shrimp *Sergia splendens* and *Gennadas valens* were the other major invertebrates, all over 100 kg km^{-2}.

8.1.9 Stock Assessment-Based Estimates

Of the species evaluated from stock assessments, gulf menhaden (*Brevoortia patronus*) had the highest biomass at 6,091.2 kg km^{-2}. Yellowfin tuna (*Thunnus albacares*) and Atlantic bluefun tuna (*Thunnus thynnus*) were the scombrids with the highest biomass at 28.7 and 11.6 kg km^{-2}, respectively. All other scombrids, istiophorids and xiphiids were less than 10 kg km^{-2}. The stock assessment-based estimates capture large pelagic fish abundances that are unaccounted for in the sample-based estimates; however, their totals do not represent all species of their kind in the Gulf of Mexico, as other large pelagic fish (primarily pelagic shark species and other scombrids) are unaccounted for in these estimates.

8.1.10 Nearshore Surveys – Brown et al. (2013)

Total nearshore fish and invertebrate biomass, which was based on data from Louisiana waters, was higher in the spring (459 kg km^{-2}) than the summer (280 kg km^{-2}). The nekton with the highest biomass during the spring were Atlantic croaker (*Micropogonias undulatus*) at 137 kg km^{-2} and blue crab (*Callinectes sapidus*) in the summer reaching 60 kg km^{-2}. Bay anchovy, spot, brown shrimp, and blue crab were the species with the highest biomass in the spring at 62, 66, 78, and 54 kg km^{-2} respectively. Major species found in the nearshore in summer include hardhead catfish and bay anchovies.

8.1.11 Nearshore Plankton Surveys – FOCAL Program

Plankton densities were higher in April than in any other spring or summer month. Anchovies (Engraulidae) and seatrout (*Cynoscion* sp.) were among the ichthyoplankton taxa with the highest densities across all months. Calanoid copepods, cyclopoid copepods, and ostracods were the dominant invertebrate zooplankton found at FOCAL station T20 during the sampling periods.

8.2 Size/Age Distributions Sampled by the Gears

Taken together, the plankton and nekton gears sample fish in a range of size and age classes, but the composite size-frequency distributions are not continuous for all size and age classes of the species' life cycle. In some cases, the discontinuities are due to certain life stages moving into estuaries or otherwise moving outside of the sampling area before the time of sampling. In other cases, the non- or under-sampled size classes are because of avoidance or other causes of low catchability. If the size classes are missing because of migration out of the affected area, they are properly excluded from the baseline estimates. However, if the size classes are under-sampled due to low catchability, the baseline values underestimate true abundance/biomass in the assessment region.

Age distributions for example species are in Figures 8-1 to 8-5. Red snapper, gray triggerfish, king mackerel, spot and Atlantic croaker are caught in both the SEAMAP Ichthyoplankton and Shrimp/Groundfish Trawl surveys. However, these two sampling gears taken together miss individuals transitioning from the post-larvae stage to older juveniles. Given the life history for gray triggerfish, red snapper and king mackerel, their absence between the larval and juvenile stage reflects inadequate sampling at the correct time and region (e.g., gear type, sampling strategy). The missing life stage for spot and Atlantic croaker, on the other hand, is likely due to their absence from the shelf sampling locations (e.g., migration into estuaries). Additionally, the Shrimp/Groundfish Trawl survey only samples juvenile king mackerel through one year olds, red snapper and Atlantic croaker through two year olds, and gray triggerfish through 3 year olds, missing the majority of adults at older ages. Spot live to about four years of age (French McCay et al. 2015b), and so most ages are sampled by the gear, when present in the sampled area. Spot and gray triggerfish are captured at a broader range of ages (to age 3) than the other species, reflecting the faster growth of red snapper, Atlantic croaker, and king mackerel to sizes/ages capable of escapement.

While an effort was made to estimate the abundance and biomass for all life stages of water column biota and this assessment covers a wide range of marine fish and invertebrates at varying life stages, some groups' data remain incomplete because of sampling limitations. For example, fast-swimming pelagic species such as tunas, mahi mahi, and swordfish are never or infrequently caught in trawls and other sampling gears. Also, the majority of the data sources used to derive density estimates have only sampled smaller fish, typically in the age 0 and 1 year classes. The analysis of stock assessment data and the inclusion of NRDA-collected data with gears that can capture larger animals did provide information on larger species and age classes for some fish taxa. Thus, the abundances and biomass estimates developed here should be considered minimal estimates for calculating baseline densities for water column biota in the GOM environments affected by the spill.

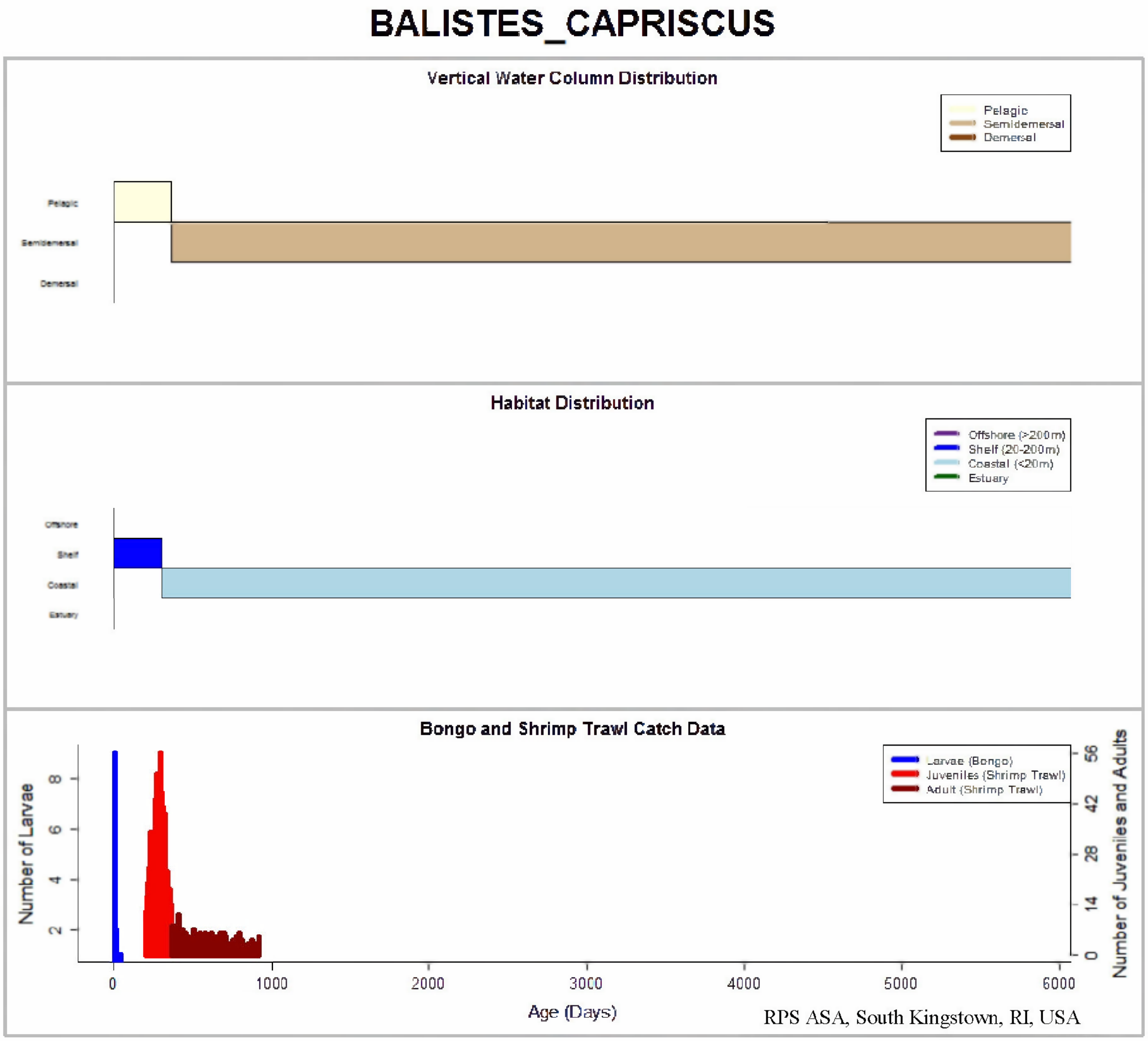

Figure 8-1. Life history and baseline data presence for gray triggerfish (*Balistes capriscus*).

The top and middle panels indicate vertical and habitat distribution from hatch through maximum age (displayed as days old on the y axis). Habitat and vertical depth information was derived from the literature and encyclopedic references. The bottom panel reflects the relative presence of gray triggerfish larvae (blue) in SEAMAP Ichthyoplankton sampling (Section 7.1) and juveniles and adults (red and dark red respectively) from SEAMAP Shrimp/Groundfish Trawl surveys (Section 7.4). Age frequency distributions were calculated from length measurements using growth equations, as described in Section 7 and French McCay et al. (2015b).

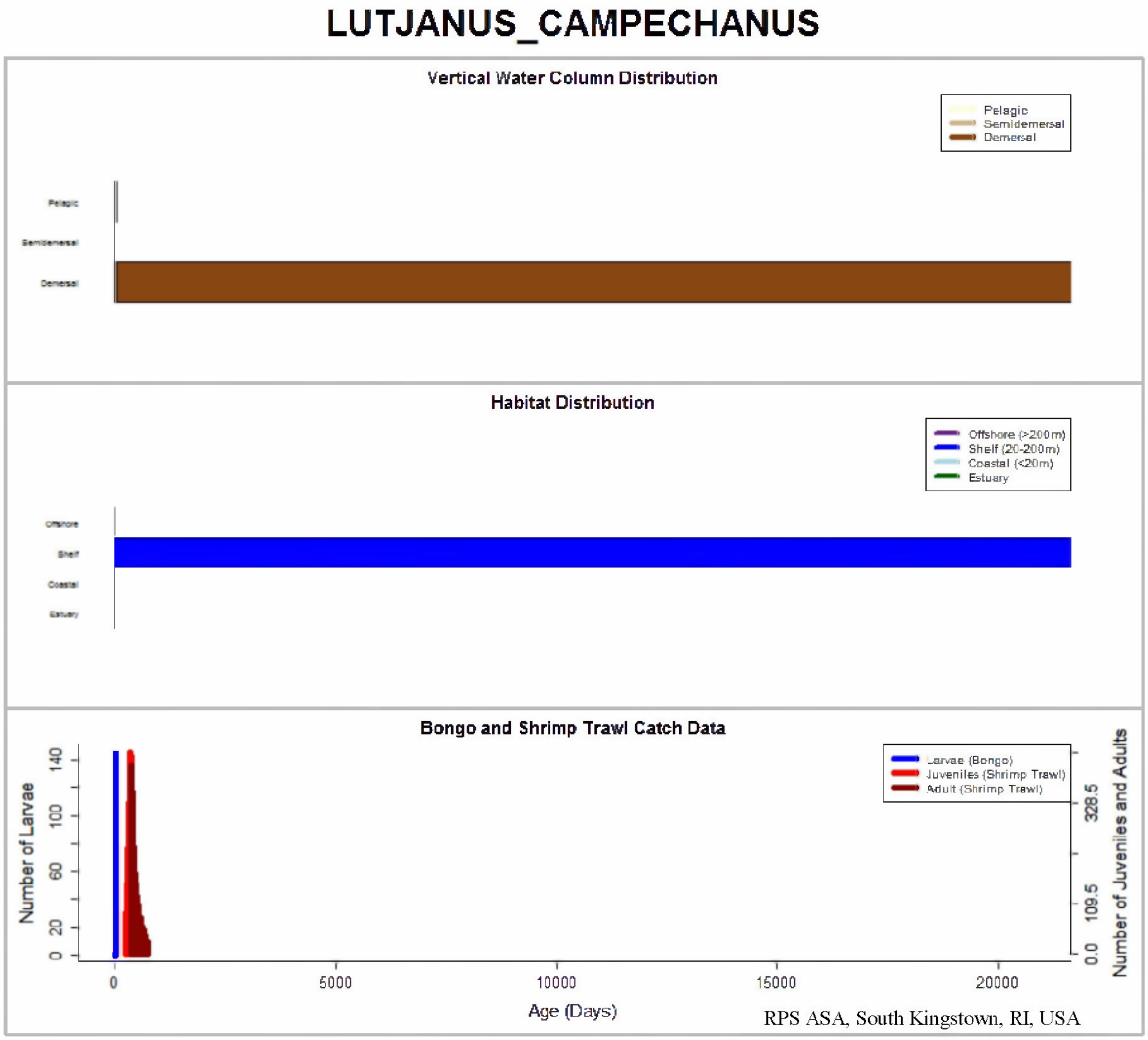

Figure 8-2. Life history and baseline data presence for red snapper (*Lutjanus campechanus*).

The top and middle panels indicate vertical and habitat distribution from hatch through maximum age (displayed as days old on the y axis). Habitat and vertical depth information was derived from the literature and encyclopedic references. The bottom panel reflects the relative presence of red snapper larvae (blue) in SEAMAP Ichthyoplankton sampling (Section 7.1) and juveniles and adults (red and dark red respectively) from SEAMAP Shrimp/Groundfish Trawl surveys (Section 7.4). Age frequency distributions were calculated from length measurements using growth equations, as described in Section 7 and French McCay et al. (2015b).

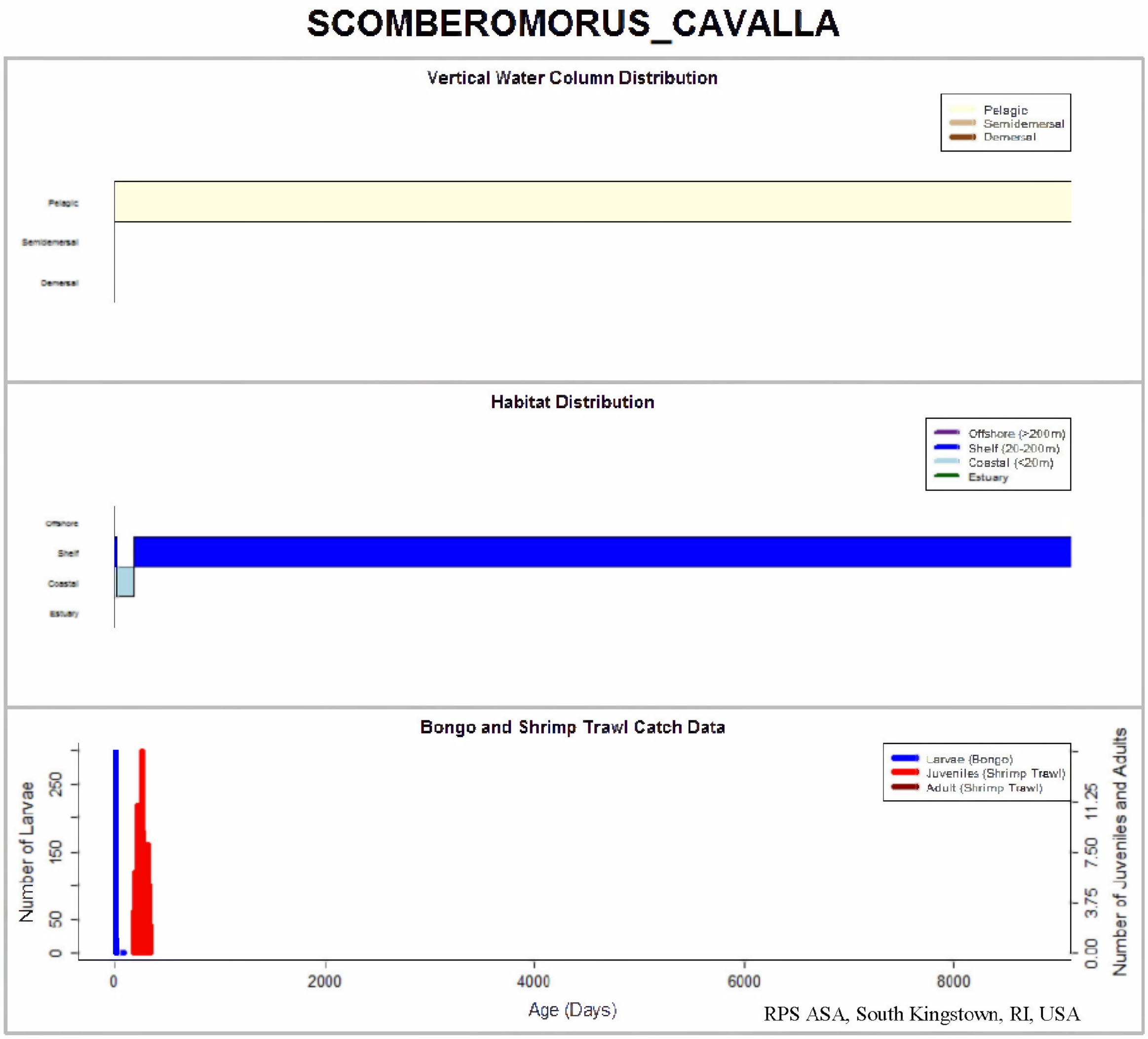

Figure 8-3. Life history and baseline data presence for king mackerel (*Scomberomorus cavalla*).

The top and middle panels indicate vertical and habitat distribution from hatch through maximum age (displayed as days old on the y axis). Habitat and vertical depth information was derived from the literature and encyclopedic references. The bottom panel reflects the relative presence of king mackerel larvae (blue) in SEAMAP Ichthyoplankton sampling (Section 7.1) and juveniles and adults (red and dark red respectively) from SEAMAP Shrimp/Groundfish Trawl surveys (Section 7.4). Age frequency distributions were calculated from length measurements using growth equations, as described in Section 7 and French McCay et al. (2015b).

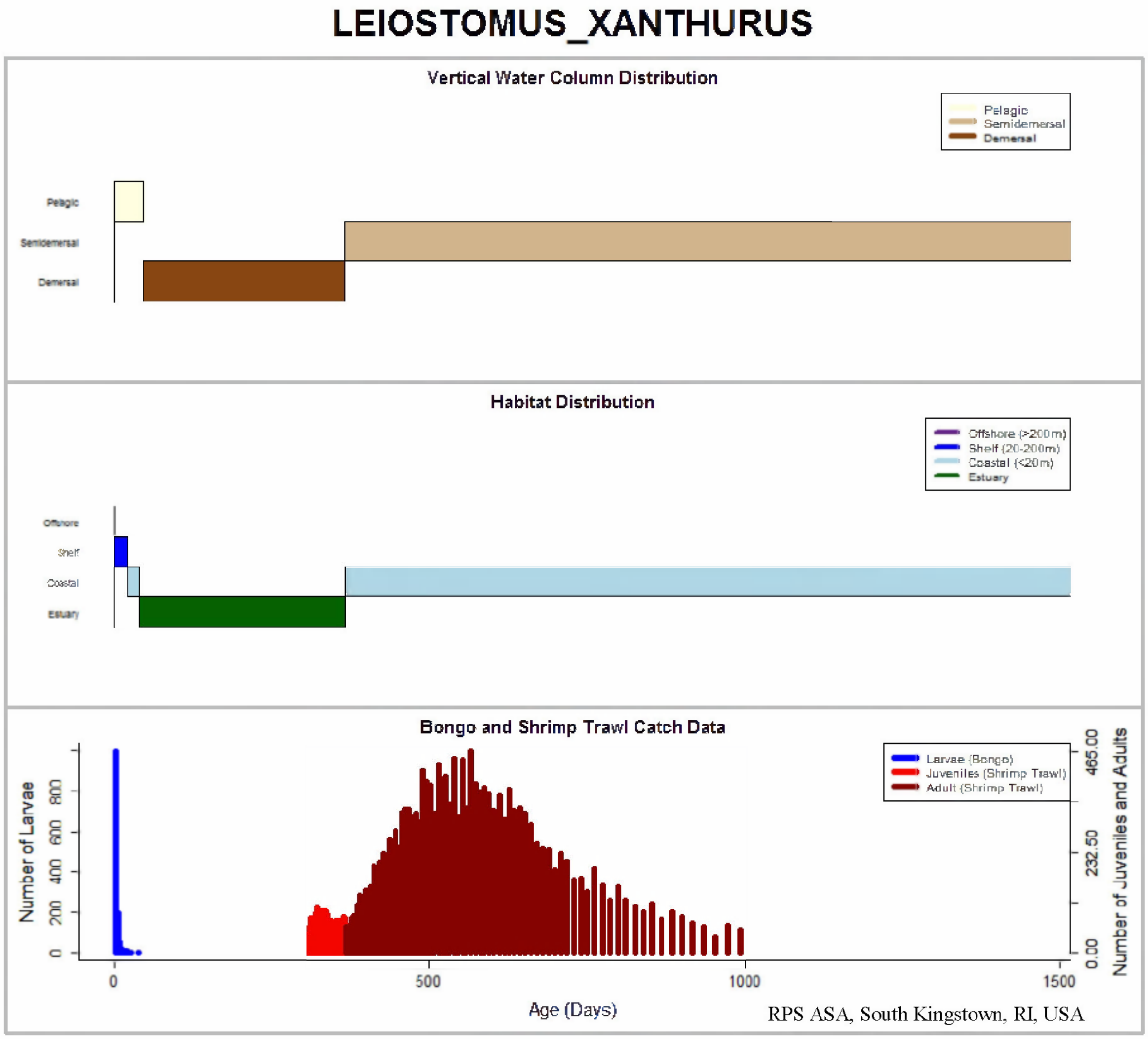

Figure 8-4. Life history and baseline data presence for spot (*Leiostomus xanthurus*).

The top and middle panels indicate vertical and habitat distribution from hatch through maximum age (displayed as days old on the y axis). Habitat and vertical depth information was derived from the literature and encyclopedic references. The bottom panel reflects the relative presence of spot larvae (blue) in SEAMAP Ichthyoplankton sampling (Section 7.1) and juveniles and adults (red and dark red respectively) from SEAMAP Shrimp/Groundfish Trawl surveys (Section 7.4). Age frequency distributions were calculated from length measurements using growth equations, as described in Section 7 and French McCay et al. (2015b).

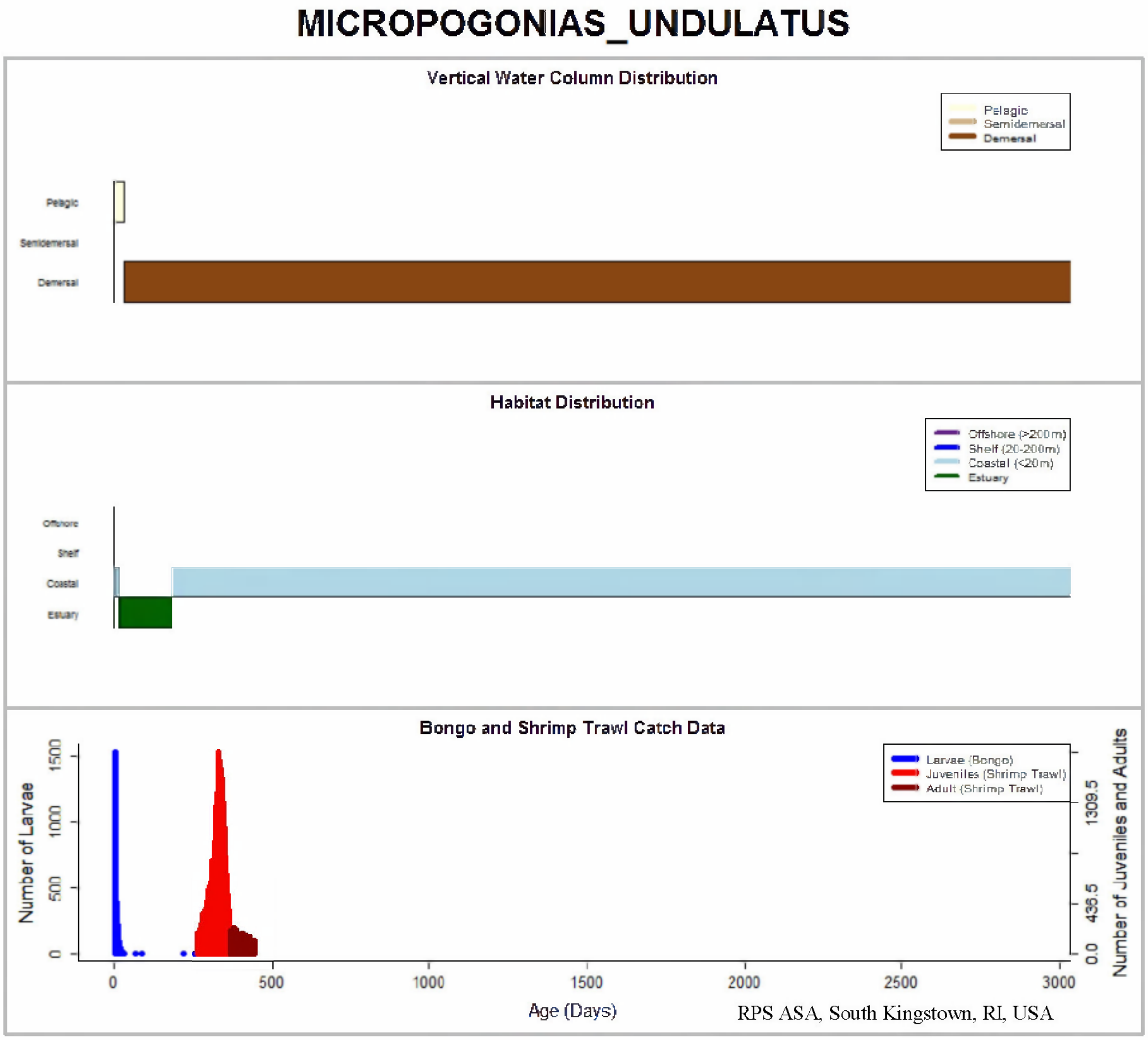

Figure 8-5. Life history and baseline data presence for Atlantic croaker (*Micropogonias undulatus*).

The top and middle panels indicate vertical and habitat distribution from hatch through maximum age (displayed as days old on the y axis). Habitat and vertical depth information was derived from the literature and encyclopedic references. The bottom panel reflects the relative presence of Atlantic croaker larvae (blue) in SEAMAP Ichthyoplankton sampling (Section 7.1) and juveniles and adults (red and dark red respectively) from SEAMAP Shrimp/Groundfish Trawl surveys (Section 7.4). Age frequency distributions were calculated from length measurements using growth equations, as described in Section 7 and French McCay et al. (2015b).

9 Baseline Volumetric Densities for Plankton

The abundances of plankton in shelf and offshore waters, as # km^{-2}, were translated to volumetric densities (# m^{-3}) using depth ranges identified within the broad depth ranges sampled by the gear used to quantify abundance. The vertical distributions of plankton were evaluated using SEAMAP historical NRDA 1-m^2 MOCNESS, NRDA 1-m^2 MOCNESS, and NRDA 10-m^2 MOCNESS datasets, which provided depth-discrete relative densities. Vertical ranges for plankton, both fish (ichthyoplankton) and invertebrate, were assigned to encompass 95% of their abundances in MOCNESS samples. (See French McCay et al. 2015a).

The volumetric density (# m^{-3}) of a taxon was calculated from CPUE (# km^{-2}) using the following equation:

$$Density = \frac{CPUE \times 10^{-6}}{(Zmax - Zmin)}$$

where *Zmin* to *Zmax* is the depth range for the taxa in meters. The estimated baseline density applies to only the depth range *Zmin* to *Zmax*, and densities are considered zero at other water depths.

Baseline volumetric densities and the associated depth ranges are tabulated for plankton in Appendix E. The list of plankton data sets are in Table 9-1. Nearshore (estuarine) data were volumetric densities sampled over the entire water column and so did not require conversion.

Table 9-1. Plankton datasets for which baseline volumetric density estimates are tabulated in Appendix E.

Fish	SEAMAP Ichthyoplankton Survey data from 1999-2009 for ichthyoplankton and small juvenile fish densities in the upper 200m in shelf and offshore waters
Fish	NRDA Plankton 1m^2 MOCNESS sample data from 2011 for ichthyoplankton densities below 200m in offshore waters
Fish	Ichthyoplankton densities in nearshore waters based on FOCAL dataset
Invertebrate	SEAMAP Invertebrate Zooplankton Survey data from 1999-2009 for invertebrate microzooplankton densities (other than decapods) in the upper 200m in shelf and offshore waters
Invertebrate	NRDA Plankton bongo sample data from 2011 for decapod larval densities in the upper 200m in shelf and offshore waters
Invertebrate	NRDA Plankton 1m^2 MOCNESS sample data from 2011 for decapod larval densities below 200m in offshore waters
Invertebrate	NRDA 10m^2 MOCNESS sample data from 2011 for planktonic invertebrate densities in offshore waters (depths of greater than 200 m)
Invertebrate	Zooplankton densities in nearshore waters based on Carassou et al. (2014)

Bootstrapping assuming simple random sampling with replacement (SRSWR) was used to estimate 95% confidence intervals (CIs) for the total CPUE of all taxa based on all samples within each data set used, i.e., for each of SEAMAP ichthyoplankton, SEAMAP zooplankton, NRDA decapods in the upper 200m, FOCAL ichthyoplankton and FOCAL zooplankton sample sets. Table 9-2 lists the data sets used and the results. We converted the 95% CI endpoints to fractions of the mean total CPUE to characterize the relative uncertainty in CPUE (Table 9-2). Thus, for the total of all taxa, we assume the uncertainty of the catchability-corrected total density is proportional to the uncertainty in total CPUE for all taxa. Similarly, for individual taxa, uncertainty of catchability-corrected density is assumed proportional to the uncertainty in the CPUE for the individual taxon. Mean volumetric densities and CIs for individual taxa are presented in Appendix E.

For the nearshore zooplankton data set, only summarized data as mean and SE (standard error) were reported in Carassou et al. (2014). Therefore, we used by-sample total zooplankton counts from 2007 FOCAL samples collected at the Mobile Bay (MB) and Dauphin Island (DI) stations (Figure 7-12) to estimate the confidence limits for nearshore invertebrate zooplankton.

Table 9-2. Bootstrap 95% confidence intervals for selected taxa/dataset combinations. All intervals are based on SRSWR over all years, seasons and regions. (SE = standard error of the mean; LB = Lower Bound; UB = Upper Bound).

Dataset and Units	Mean	SE	LB	UB	LB / Mean	UB / Mean
SEAMAP ichthyoplankton, 1999-2009 (#/m^2)	147.4	4.6	138.2	156.5	0.9377	1.0620
SEAMAP zooplankton, 1999-2009 (#/m^2)	35,538	1,626	32,467	38,773	0.9136	1.0911
FOCAL ichthyoplankton, 2007-2009 (#/m^3)	7	1	5	9	0.7278	1.3425
FOCAL zooplankton, 2007 (#/m^3)	98	22	58	141	0.5979	1.4403
NRDA decapods in the upper 200m, 2011 (#/m^2)	1,240.6	173. 8	922.8	1,611.0	0.7438	1.2986

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Appendix A. Available Biological Datasets for Developing Baseline Abundance and Biomass Estimates

[This appendix is a separate Word file.]

Appendix B. Review of Catchability

[This appendix is a separate Word file.]

Appendix C. Fraction by Life Stage and Age Class for Fish Caught in Ichthyoplankton Samples

[This appendix is a separate Word file.]

Appendix D. Results – Baseline Abundance and Biomass of Water Column Fish and Invertebrates

[This appendix is a separate Excel file.]

Appendix E. Results – Depth-Discrete Densities of Planktonic Fish and Invertebrates

[This appendix is a separate Excel file.]

Technical Reports for Deepwater Horizon Water Column Injury Assessment

WC_TR.10: Evaluation of Baseline Densities for Calculating Direct Injuries of Aquatic Biota During the Deepwater Horizon Oil Spill

Appendix A. Available Biological Datasets for Developing Baseline Abundance and Biomass Estimates

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Project Number: 2011-144
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A.1 Introduction

This appendix provides a summary of existing data characterizing the abundance of fish and invertebrates in the vicinity of the DWH spill. Note that this appendix was originally written in September 2010 and only the discussions on SEAMAP collected data have been updated using the best of RPS ASA's knowledge. A further literature review would need to be conducted to incorporate other publically available data since late 2010. An additional literature synthesis was not conducted after September 2010 because it was decided at that time that the most complete datasets to use for injury quantification were those that are listed in the WC_TR.10 Main Report. This summary has been divided by the synthesis of literature based on life stages (e.g., plankton, and juvenile/adult fish and invertebrates) and geographic delineation (e.g., shelf and offshore species).

A.2 Plankton Fish and Invertebrates

Table A-1 provides potential data sources for deriving plankton baseline densities. Note that plankton data were sought for embayments, shelf waters (depths <200 m), and offshore waters (depths >200 m).

Table A-1. Available Biological Data Sources for Plankton Fish and Invertebrates.

Source	Geographic Location	Gear	Sampling Period	Available Data
SEAMAP (NMFS, FL, AL, MS, LA, TX) – Spring Plankton Survey	Stations are located at ~56 km or ½ degree intervals along the grid from offshore TX to FL >200 m depth contour (Figure A-1)	61 cm bongo net with 0.333 mm mesh sampled in oblique tow path from max depth of 200 m or to 2-5 m off bottom	April to early June [note: LA has taken additional plankton samples during other seasons as part of this program]	Data available as early as 1982 and into 2012
SEAMAP (NMFS, FL, AL, MS, LA, TX) – Fall Plankton Survey	Stations are located on the shelf, generally in waters <200 m depth (Figure A-2)	61 cm bongo net with 0.333 mm mesh sampled in oblique tow path from max depth of 200 m or to 2-5 m off bottom	Late August through September [additional sampling by LA and MS]	Sampling has occurred for 22 years
SEAMAP (NMFS, FL, AL, MS, LA, TX) – Winter/Summer Groundfish & Shrimp Survey – Plankton	NMFS, MS, and LA collect ichthyoplankton data in conjunction with the Groundfish Survey (Figure A-3)	61 cm bongo net with 0.333 mm mesh sampled in oblique tow path from max depth of 200 m or to 2-5 m off bottom	June and July [aimed to capture the movement of penaeid shrimp during migration from bays to the open Gulf]	Over 28 years of sampling

Source	Geographic Location	Gear	Sampling Period	Available Data
SEAMAP (USGS sponsored report)	MS to FL (Figure A-4); stations are further inshore of data described in more recent SEAMAP Atlases (Rester and Noble 2009, 2010)	Bongo and neuston nets	April to early June; analyzed data from 1982-1999	likely available within the 25 years worth of full SEAMAP data
SEAMAP (specifically neuston sampling)	533 neuston samples taken off coast of Louisiana, Mississippi, Alabama, and Florida coasts (Figures A-5 and A-6)	single or double 2x1 m pipe frame neuston net with 0.947 mm mesh netting towed at surface with frame half submerged for 10 min; taken @ arrival to station, regardless of time of day	April to early June	25 years worth of data available; however, neuston tows are not carried out at every station, usually only as time permits
LOOP ichthyoplankton sampling	Inshore and offshore SE LA, near Fourchon, LA from freshwater wetlands to mid-continental shelf	0.5 m 0,080 mm mesh, 0.5 m, 0.153 mm mesh, 1 m 0.363 mm mesh plankton nets towed at surface; 0.60 m, 0.363 mm mesh bongo nets towed stepped-oblique, 3-strata horizontal, or 2-strata stepped oblique	Monthly, specific months, or quarterly, depending on station and year	Varies by gear, but sampling program ran from 1978 until 1995.
FL Institute of Oceanography, FWC, USF - RV Weatherbird II cruise	SEAMAP Stations in coastal areas of the Florida panhandle and/or Big Bend region (NMFS statistical zones 7 – 10; Figures A-7 and A-8)	SEAMAP bongo net (surface to depth of pycnocline – time will vary depending on depth and rate of deployment/retrieval); SEAMAP neuston net (surface with half of the net submerged – 10 minute tow); SIPPER oblique cast at every other station	May 5-17, 2010	On-going
Compass Port Survey	Alabama coastal waters (Figure A-9)	BIONESS; Discrete depths sampling, collected over all seasons using various mesh types	2004-2006	2004-2006

Source	Geographic Location	Gear	Sampling Period	Available Data
Fisheries Oceanography of Coastal Alabama (FOCAL) survey	Alabama coastal waters and Mobile Bay (Figure A-9)	BIONESS; Discrete depths sampling, collected over all seasons using various mesh types	2006-present	2006-2010

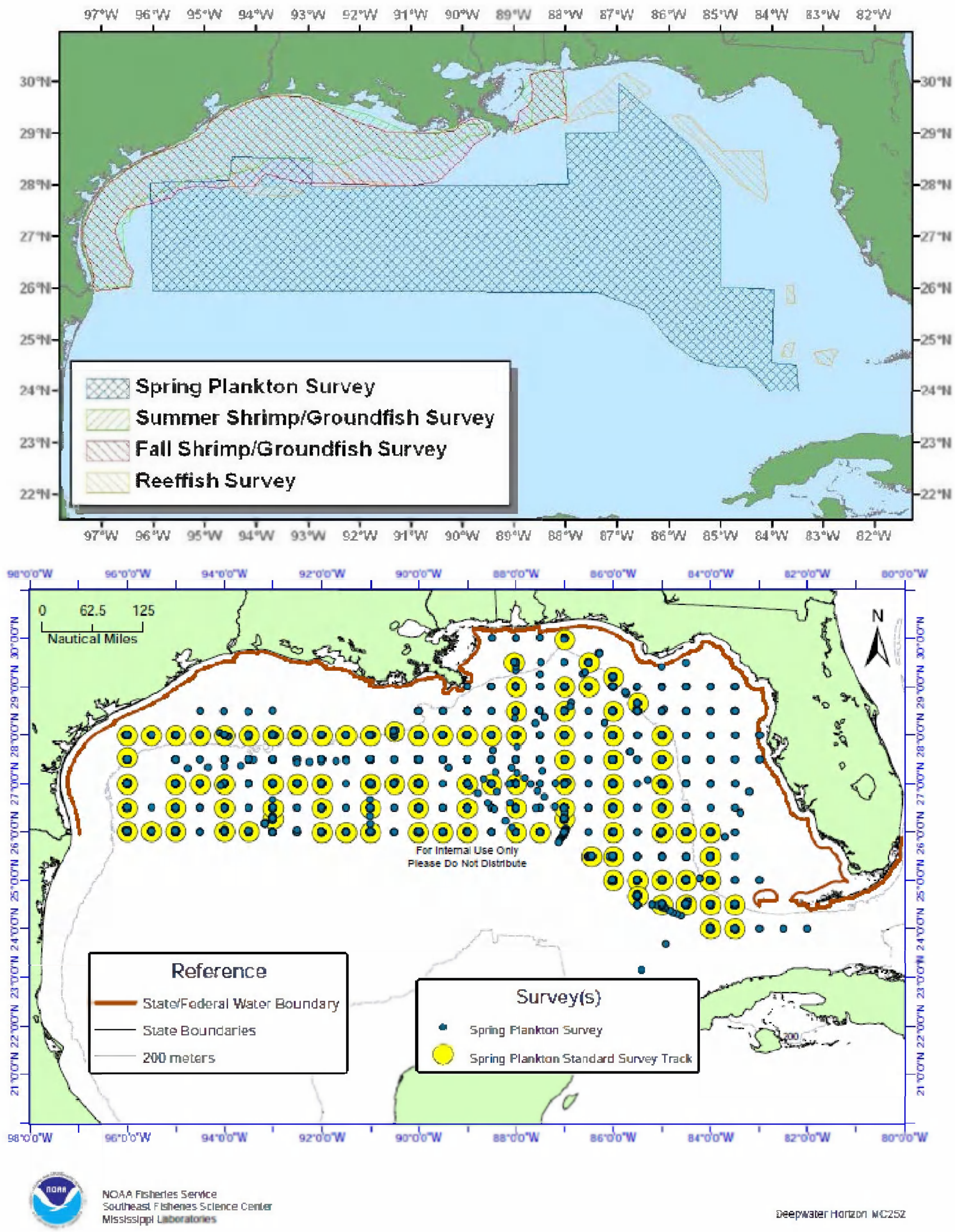


Figure A-1. Summary of various SEAMAP surveys (top), and locations of SEAMAP Spring Plankton Survey effort from 1982-2008 (bottom).

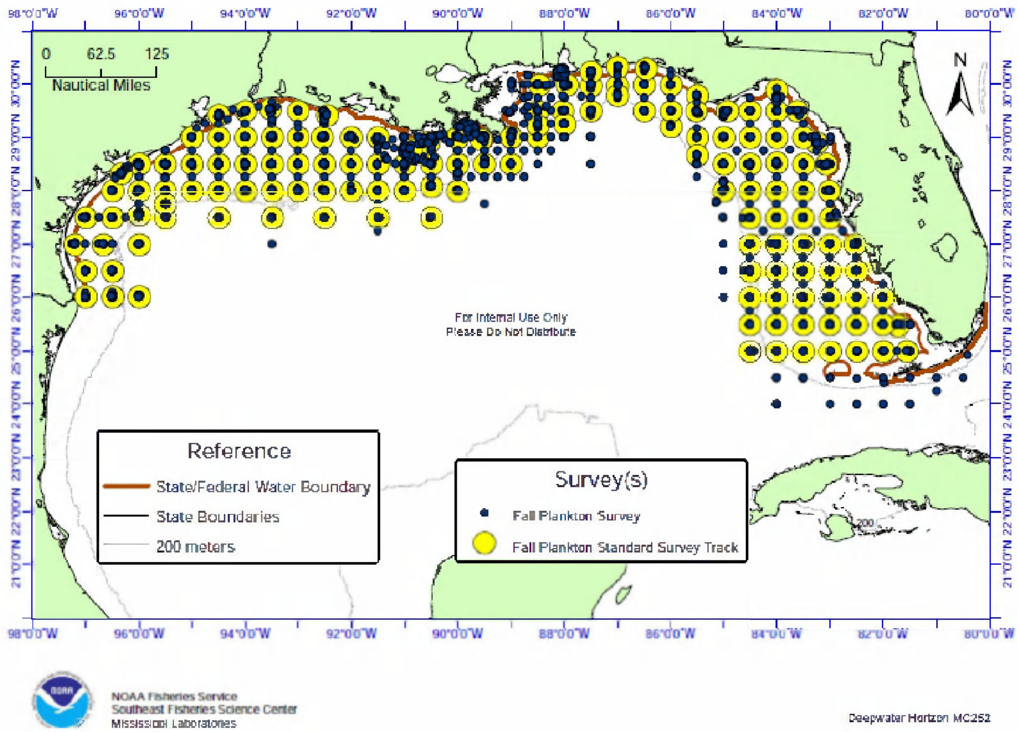


Figure A-2. Locations of SEAMAP Fall Plankton Survey effort from 1986-2008.

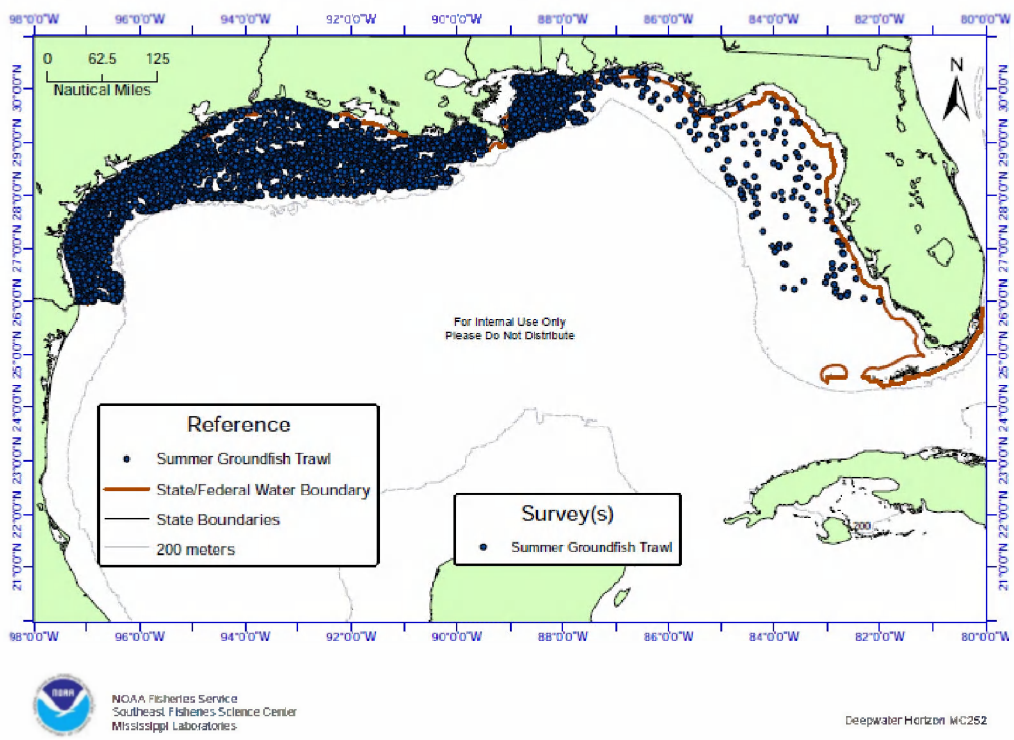


Figure A-3. Locations of SEAMAP Summer Groundfish Plankton Survey effort from 1987-2009.

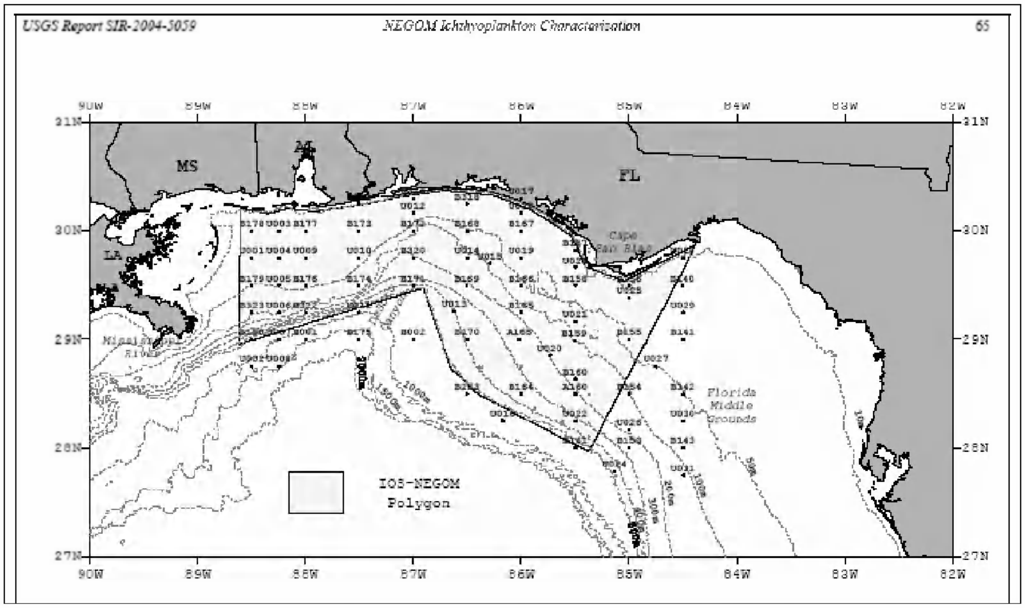


Figure A-4. SEAMAP Plankton survey data (1982-1999) collected at 72 sites analyzed in the USGS study. Source: Lyczkowski-Shultz et al. (2004).

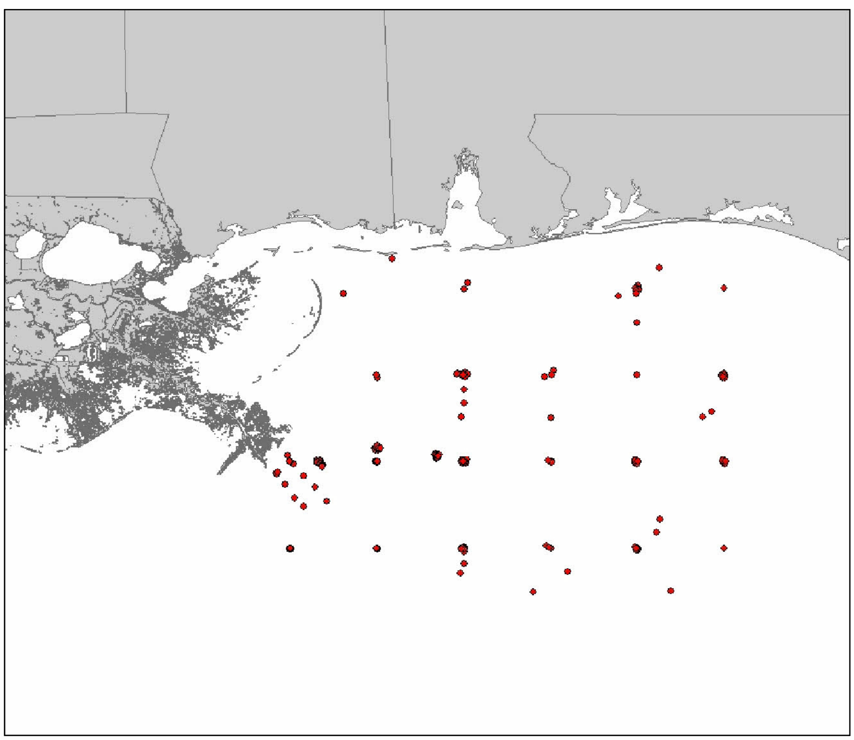


Figure A-5. Locations of SEAMAP neuston samples collected from 1982-2008.

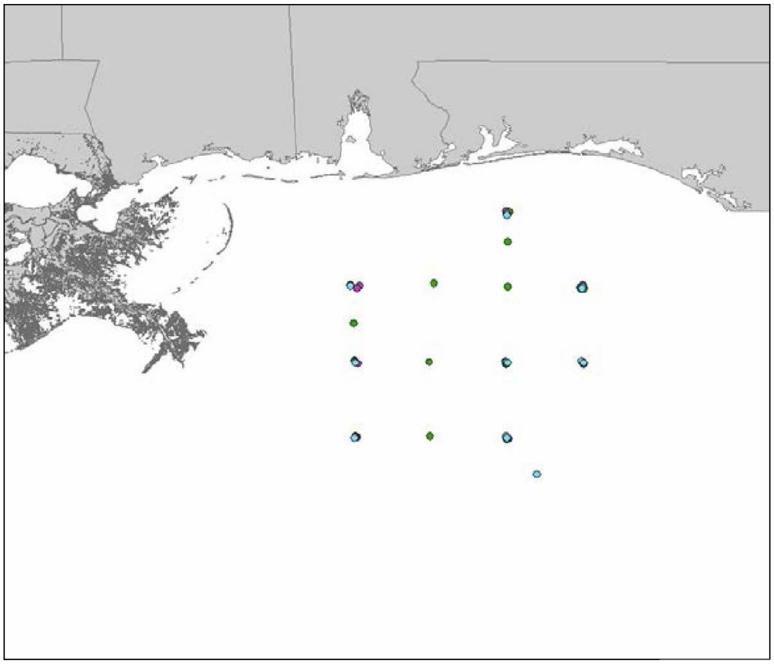


Figure A-6. Locations of SEAMAP neuston samples collected from 2006-2008, magenta points=2006 (16 samples), green=2007 (21 samples), and blue=2008 (14 samples).

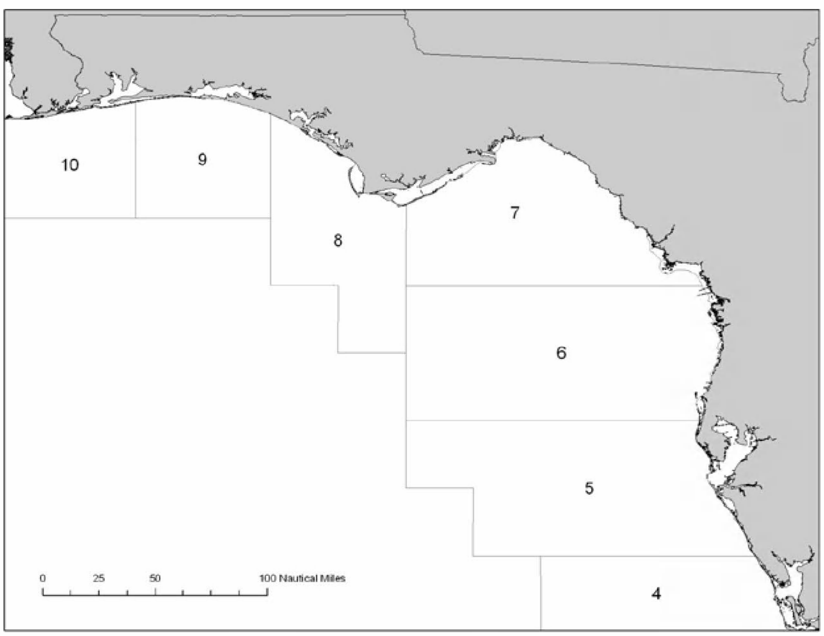


Figure A-7. NMFS statistical shrimp zones (4-10) within coastal Florida waters.

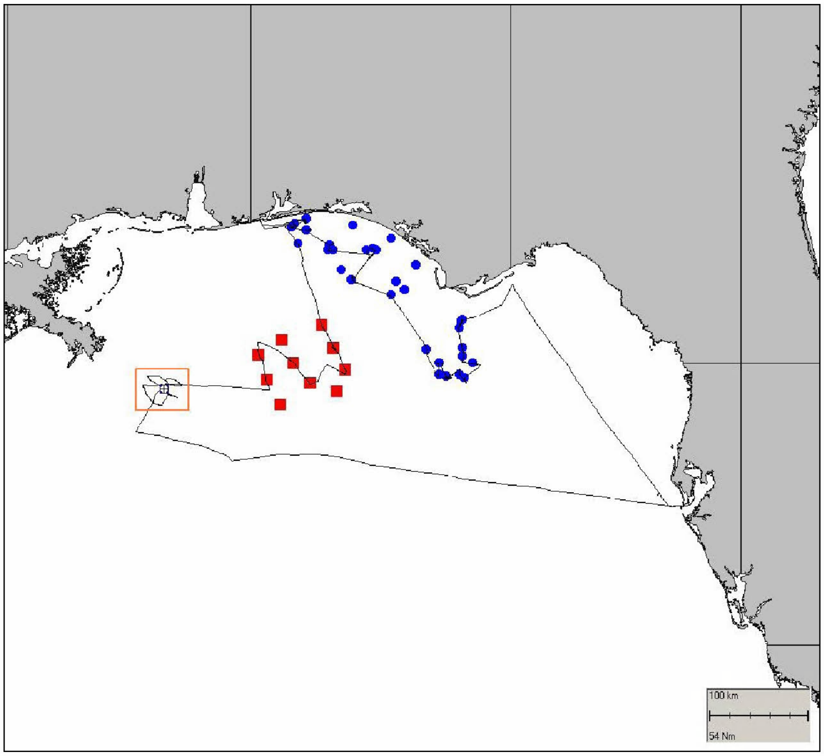


Figure A-8. Ship trackline and sampling coverage of the FL Institute of Oceanography, FWC, USF - RV Weatherbird II cruise - SEAMAP/SIPPER May 5-17, 2010. Black line = ship track, Blue dots = SEAMAP stations, Red Dots = baseline SIPPER stations, Orange square = spill site SIPPER transects.

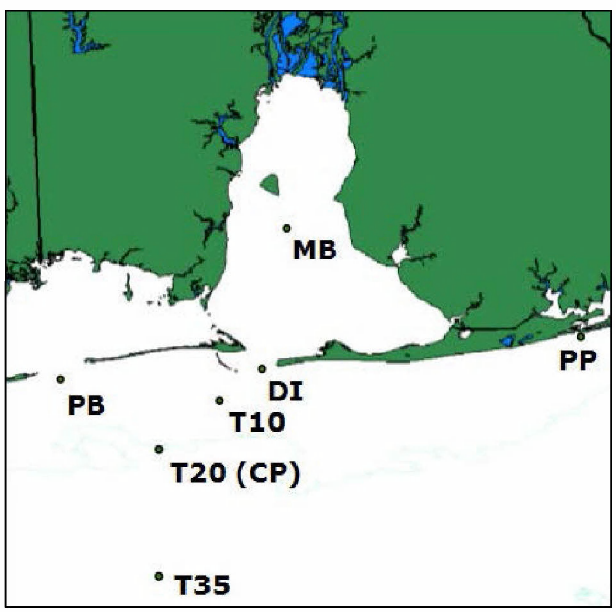


Figure A-9. Stations monitored in coastal Alabama as part of the Dauphin Island Sea Land Fisheries Oceanography of Coastal Alabama (DISL FOCAL) program. Site T20 also represents the Compass Port (CP) station from 2004-2006 (map source: http://focal.disl.org/research.html).

The literature was also reviewed to determine if previous work could be used to assess nearshore (estuarine) plankton densities. Below is a brief description on some of the data sets reviewed:

Dauphin Island Sea Laboratory's Fisheries Oceanography of Coastal Alabama (FOCAL) program

The Dauphin Island Sea Laboratory's Fisheries Oceanography of Coastal Alabama (FOCAL) program (Dauphin Island Sea Lab 2009) consists of a cross-shelf survey that originates within Mobile Bay and employs a version of the BIONESS (Bedford Institute of Oceanography, Net Environmental Sampling System) system called a "Mininess" for sampling (Figure A-9). Oblique samples taken over the water column from 2007-2009 using 333 µm mesh nets have been analyzed and ichthyoplankton and small zooplankton have been enumerated.

As described in Section 4.1.1.1 of the Biological Technical Report, after reviewing available data and literature describing estuarine plankton (described below), the FOCAL dataset was chosen to estimate densities for nearshore ichthyoplankton. The FOCAL dataset provided the most recent assessment for baseline fish larval densities (2007-2009), and contained the highest number of samples, providing the best estimate of the temporal variability in plankton densities. The FOCAL dataset also had true embayment samples to estimate nearshore densities, while the other sources' samples were all on the inshore shelf. However, the database currently available does not have invertebrate zooplankton data fully processed, thus this FOCAL database was not used to quantify invertebrate zooplankton densities. Instead, densities for these taxa were derived from Carassou et al. (2014). This study analyzed FOCAL invertebrate zooplankton data using completely processed samples from 2005-2009. A further description of this dataset can be found in the main report.

Rakocinski et al. 1996

A study by Rakocinski et al. (1996) estimated densities for ichthyoplankton in coastal Mississippi waters from November 1979 to October 1980. Sampling was conducted monthly throughout the year at 22 stations along 6 distinct transects (Figure A-10). The top and bottom halves of the water column were measured separately at each station (depth ranges: 1.5-17 m) with 1-m diameter, 335-µm mesh, opening–closing, conical-ring plankton nets. Larvae were identified to the lowest possible taxonomic level, with standard densities of individual taxa expressed as number/100m^3 for each collection.

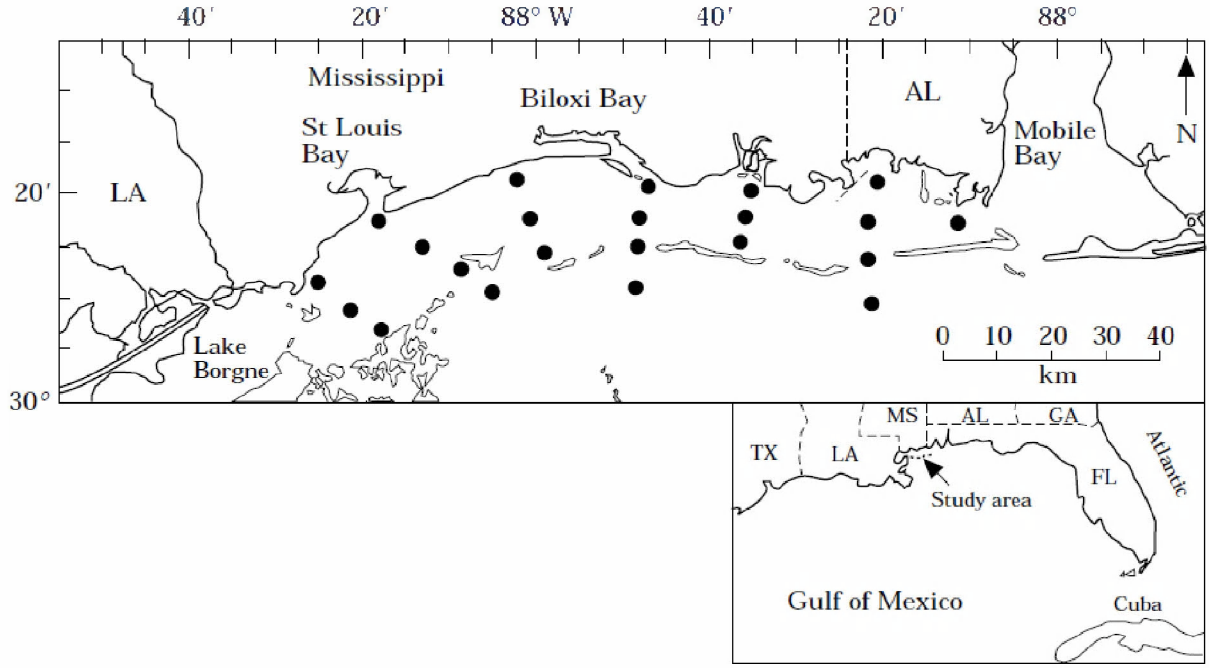


Figure A-10. Stations sampled in Mississippi Sound as part of the Rakocinski et al. (1986) study (map source: Rakocinski et al. 1986)

Hernandez et al. 2003; Hernandez and Shaw 2003

Hernandez et al. (2003) and Hernandez and Shaw (2003) summarized ichthyoplankton densities caught from 1995 to 1997 off Louisiana to assess larval fish communities in waters susceptible to oil and gas infrastructure development. Three stations were sampled to assess three distinct community assemblages: coastal (22 m), offshore (60 m), and blue water/tropical (219m) (Figure A-11). The blue water station was sampled monthly for 11 months, and bi-weekly for the other sites in spring and summer. Sampling occurred at night using both light traps and 60-cm-diameter, 333-μm mesh nets. Larval fish densities are provided at various taxonomic levels and time frames for each region as number/100 m^3. Size ranges (mm) are also provided in Hernandez and Shaw (2003).

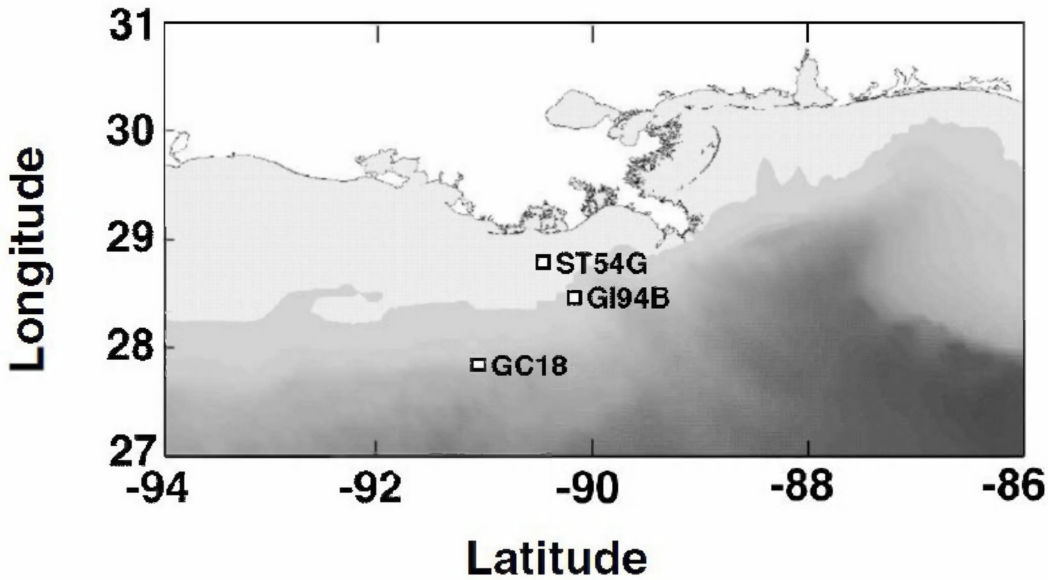


Figure A-11. The coastal (ST54G), offshore (GI94B), and blue water/tropical (GC18) sites analyzed in the Hernandez et al. (2003) and Hernandez and Shaw (2003) studies (map source: Hernandez et al 2003).

Ditty 1986

From November 1981 to October 1982, Ditty et al. (1986) collected monthly ichthyoplankton samples in Louisiana shelf waters. The samples were collected from six stations within a 3.2 km^2 grid (depth: 10-12 m) located 12.9 km south-southwest of Caminada Pass. Collections were taken with a 60 cm paired-net opening and closing bongo-type net, equipped with 363µm mesh. The nets sampled at three discrete depths: surface, mid-depth, and near-bottom. Monthly densities for fish larvae (identified to finest discernible taxon) were reported for the area in number 100 m^{-3}.

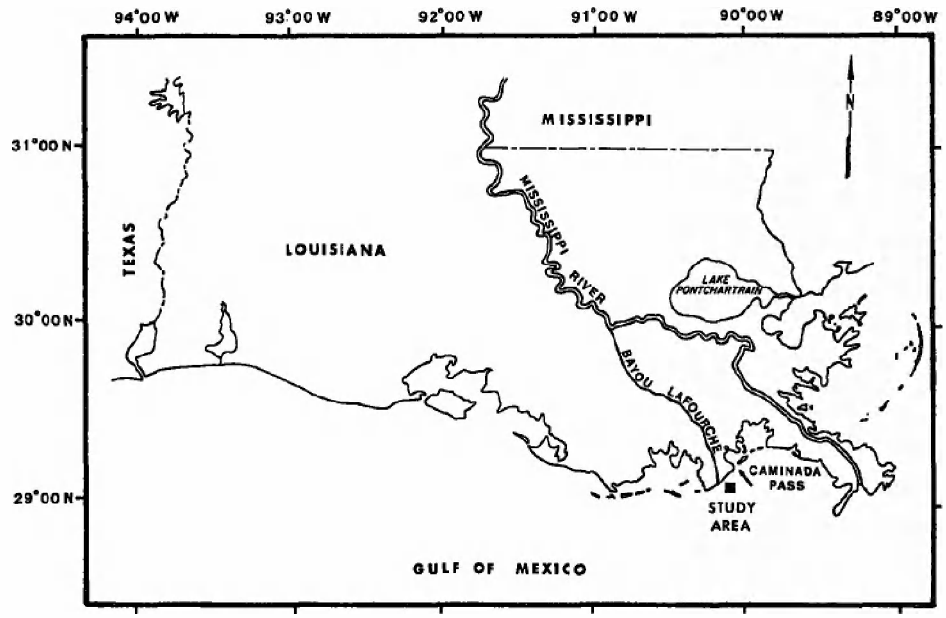


Figure A-12. Sampling grid in coastal Louisiana analyzed by Ditty (1986) (map source: Ditty 1986).

<u>Shaw et al. 1985</u>

Shaw et al. (1985) sampled for Gulf menhaden (*Brevoortia patronus*) from December 1981 to April 1982. Field collections occurred in continental shelf waters from west of the Sabine River, Texas to the east of the Mermentau River, Louisiana. Samples were taken at 37 stations spaced over five transects, with some transects extending to 200m offshore (Figure A-13). Plankton collections were made with an open-and-closing bongo-type net with 60-cm paired net frame. The paired nets were equipped with 500 and 335 µm meshes. Egg densities are described within the text in general geographic context, and expressed as number/100 m^3. Egg and larval densities (number/100 m^3) are also displayed on a map of the Texas-Louisiana shelf using a bubble plot.

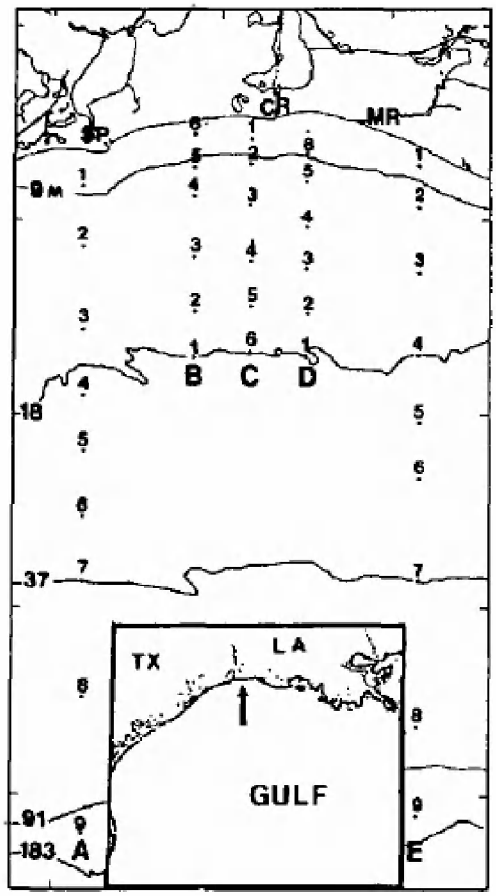


Figure A-13. Stations sampled in Texas and Louisiana waters as part of the Shaw et al. (1985) study (map source: Shaw et al. 1985).

A.3 Juvenile and Adult Fish and Invertebrates

A.3.1 Shelf Waters (<200 m deep)

Table A-2 provides potential data sources for deriving juvenile and adult fish and pelagic or demersal invertebrate baseline densities in shelf waters.

Table A-2. Available Biological Data Sources for Fish and Invertebrates in Shelf Waters (<200 m deep).

Source	Geographic Location	Gear	Sampling Period	Available Data[1]
SEAMAP Shrimp/Groundfish surveys (NMFS, FL, AL, MS, LA, TX)	Randomly chosen sites in areas stratified by depth and statistical area (Figures A-3, A-7, A-14; Rester and Noble 2009)	Trawl stations sampled by NMFS, Alabama, Mississippi and Louisiana are made with a standard SEAMAP 40-ft net; Texas sampled with a 20-ft net; 2-120 m depths	Spring and fall LA has sampled additional seasons (summer and winter) in recent years.	Data are compiled for up to 2009 (pre spill) with some post spill data also available (2010 on)
NMFS surface long-line survey	Varied area coverage within Gulf and Atlantic (e.g., adaptive based upon temperature/current regimes) depths >183 m	5 nautical mile mainline fishing 200 hooks fishing >= 40 m	Varied periods	Since 2005 - Data are based on catch, may only be available as CPUE (# of fish per long-line set), does not depict biomass or depth habitat
NMFS bottom long-line survey	Gulf wide, 9-366 m, proportional allocation within statistical zones (since 2001) (Figure A-15)	1.0 nautical mile mainline fishing 100 hooks during a 1-hr set	Primarily July-September	Last known update in February 2014
NMFS Small Pelagics/Deep Trawl Survey	Gulf of Mexico extending from Brownsville, TX to Tampa, FL in 40-500 m depths (Figure A-16)	Deepwater bottom trawl (90 feet high opening)	October-November	2002-2004, 2006-present
Reef fish: NMFS Pascagoula	Gulf Wide, 14 -150 m, focused on outer shelf topographic features (Figure A-17)	Drop cameras, traps, adding vertical hook and line gear 2010	Summer-fall,	1992-1997; 2001-2002, 2004-present
Reef fish: NMFS Panama City	Shrimp zones 7-9, 7-40 m, across shelf	Drop cameras, traps, adding vertical hook and line gear 2010	Summer-fall	Since since 2004- (video) Since 2003 (trap)
Marine reserve monitoring: NMFS Pascagoula/Panama City	Madison/Swanson reserves, and Twin Ridges control site, W Florida shelf	Drop cameras (laser and stereo), stratified by habitat within reserves	Winter-spring	Since 2001

[1] Data Availability as of September 2010

Source	Geographic Location	Gear	Sampling Period	Available Data[1]
Riley's Hump area survey: NMFS Beaufort	North and South Tortugas Ecological Reserve	SCUBA Diver visual census (transect based)	2002 to present	Species comp., abundance, size comp.
Louisiana	Several locations on eastern side of Mississippi delta, including one in Chandeleur Islands (Figure A-18)	Fishery-independent nearshore surveys for shrimp and groundfish	Since 1966 for 16 ft. trawl surveys, 1986 for 50 ft. beach seine, 750 ft. experimental gill net, and 750 ft. trammel net	1967-present
LA W& F	Breton Sound, MS Sound	Trawl surveys (6-foot & 16-foot), salinities, temperatures, Secchi disk		
LOOP otter trawl sampling	Inshore and offshore SE LA, near Fourchon, LA from freshwater wetlands to mid-continental shelf	16 ft. flat otter trawl	Monthly or quarterly, depending on station and year	Varies by gear, but sampling program ran from 1978 until 1995.
Louisiana State University (Wilson et al.; 2006)	Studied fish populations associated with four platforms to east of LA waters on shelf; stations in 30-200 m depths (Figure A-19)	Hydroacoustics and point count visual surveys to estimate species biomass and composition	1998-2003, beginning in eastern region (Figure A-17)	Data grouped by depth and trophic group
LA Artificial Reef Program (LDFW) funded 3 yr project by Jim Cowan (LSU)	Two established artificial reefs (EI-322 and EI-324) and two standing platforms (EI-325 and EI-346) in offshore Eugene Island area approx. 80 miles SW of Cocodrie	Objectives : acoustic biomass estimates, red snapper trophic ecology, red snapper age and growth, benthic community/prey characterization, food web analysis	2007-2010	
ALDCNR/MRD	Alabama State Waters	Gill net, trawl, seine, DO, temp, salinity	Sites sampled monthly	To Present
FWC/FWRI	Choctawhatchee Bay/Santa Rosa Sound (Estuarine)	6.1-m otter trawl 21.3-m beach seine	1992 – 1996	All
FWC/FWRI	Apalachicola Bay (Estuarine)	6.1-m otter trawl 21.3-m beach seine 183-m haul seine	1998 – ongoing	1998 – 2009
FWC/FWRI	St. Andrew's Bay (Estuarine)	6.1-m otter trawl 183-m haul seine	2008 – ongoing	2008 – 2009

Source	Geographic Location	Gear	Sampling Period	Available Data[1]
FWC/FWRI	St. Mark's (Estuarine)	6.1-m otter trawl 183-m haul seine	2008 – ongoing	2008 – 2009
FWC/FWRI	Ecofina (Estuarine)	6.1-m otter trawl 183-m haul seine	2008 – ongoing	2008 – 2009
FWC/FWRI	Steinhatchee (Estuarine)	6.1-m otter trawl 183-m haul seine	2008 – ongoing	2008 – 2009
FWC/FWRI	Cedar Key (Estuarine)	6.1-m otter trawl 21.3-m beach seine 183-m haul seine	1996 – ongoing	1996 – 2009
FWC/FWRI	St. Joseph's Sound (Estuarine)	6.1-m otter trawl 21.3-m beach seine 183-m haul seine	2009 – ongoing	2009
FWC/FWRI	Tampa Bay (Estuarine)	6.1-m otter trawl 21.3-m beach seine 183-m haul seine	1989 – ongoing	1989 – 2009
FWC/FWRI	Sarasota Bay (Estuarine)	6.1-m otter trawl 21.3-m beach seine 183-m haul seine	2009 – ongoing	2009
FWC/FWRI	Lemon Bay (Estuarine)	6.1-m otter trawl 21.3-m beach seine 183-m haul seine	2009 – 2010	2009
FWC/FWRI	Charlotte Harbor (Estuarine)	6.1-m otter trawl 21.3-m beach seine 183-m haul seine	1989 – ongoing	1989 – 2009
FWC/FWRI	Estero Bay (Estuarine)	6.1-m otter trawl 21.3-m beach seine 183-m haul seine	2005 – 2007	2005 – 2007
FWC/FWRI	Florida Bay (Estuarine)	6.1-m otter trawl 21.3-m beach seine 183-m haul seine	2006 - 2009	2006 - 2009
FWC/FWRI	Tampa Bay/Charlotte Harbor (Gulf of Mexico)	20-m bottom trawl Hydroacoustic	Spring 1994 – 1999 2001 – Ongoing	1994 – 1999 2001 – 2009
FWC/FWRI	Tampa Bay/Charlotte Harbor (Gulf of Mexico)	20-m bottom trawl Hydroacoustic	Fall 2004 – 2007	2004 – 2007
FWC/FWRI	Tampa Bay/Charlotte Harbor (Gulf of Mexico)	Mapped Habitat Suitability Models (HSM) for estuarine fish and shrimp; Rubec et al. 2009		

Source	Geographic Location	Gear	Sampling Period	Available Data[1]
FWC/FWRI	NOAA Stat Zone 8 (Gulf of Mexico)	Vertical hook and line gear	Summer/Fall 2009 - ongoing	2009
FWC/FWRI	Florida Middle Grounds (Gulf of Mexico)	Drop cameras Traps Vertical hook and line gear	Summer/Fall 2007 - ongoing	2007 and 2009
FWC/FWRI	NOAA Stat Zones 4-5 (Gulf of Mexico)	Drop cameras Traps Vertical hook and line gear	Summer/Fall 2008 - ongoing	2008 - 2009
FWC/FWRI	Tortugas (Gulf of Mexico)	Traps Vertical hook and line gear	Summer/Fall 2008 - ongoing	2008 - 2009
Reef fish visual census	Florida Keys/ Dry Tortugas	SCUBA Diver visual census	1979 to present	Species comp., abundance, size comp.
University of West Florida (Dr. Will Patterson)	Coastal AL and FL panhandle (Figure A-20)	Video samples with ROV for fish and invertebrate community and fish size structure; hook and line; otoliths for aging, stomach content analysis and muscle tissue for stable isotope analysis	Quarterly basis for past 6 years	Review in Bull Mar. Sci., couple papers in GCFI; Dustin Addis future article on tagging study
TPWD – Texas artificial reef program (re Doug Peter, LADWF)	Texas – surface to 40m depth	Collected species composition and relative abundance data for fish on artificial reefs and standing platforms from video and roving diver surveys	1993-2007	Doug Peter checking with TPWD for station locations and whether surveys continued beyond 2007
National Coastal Assessment (NCA: EPA/ORD and FL, AL, MS, LA, TX)	Estuaries and near-coastal waters from Texas/Mexico border to Florida Bay, FL (Probabilistic survey design stratified by state)	Standard otter trawl (4.9 or 6.1 m) or beach seine	Annual Surveys conducted in summer (June – September)	Data are available from 2000-2006

Source	Geographic Location	Gear	Sampling Period	Available Data[1]
FSUCML Chris Stallings	St. George Sound, St. Joe Bay, St. Marks	Rollerframe trawl	4 in each area monthly 05/2009-08/2009	Rollerframe trawl survey completed last summer over seagrass to look at bycatch in the bait shrimp industry.

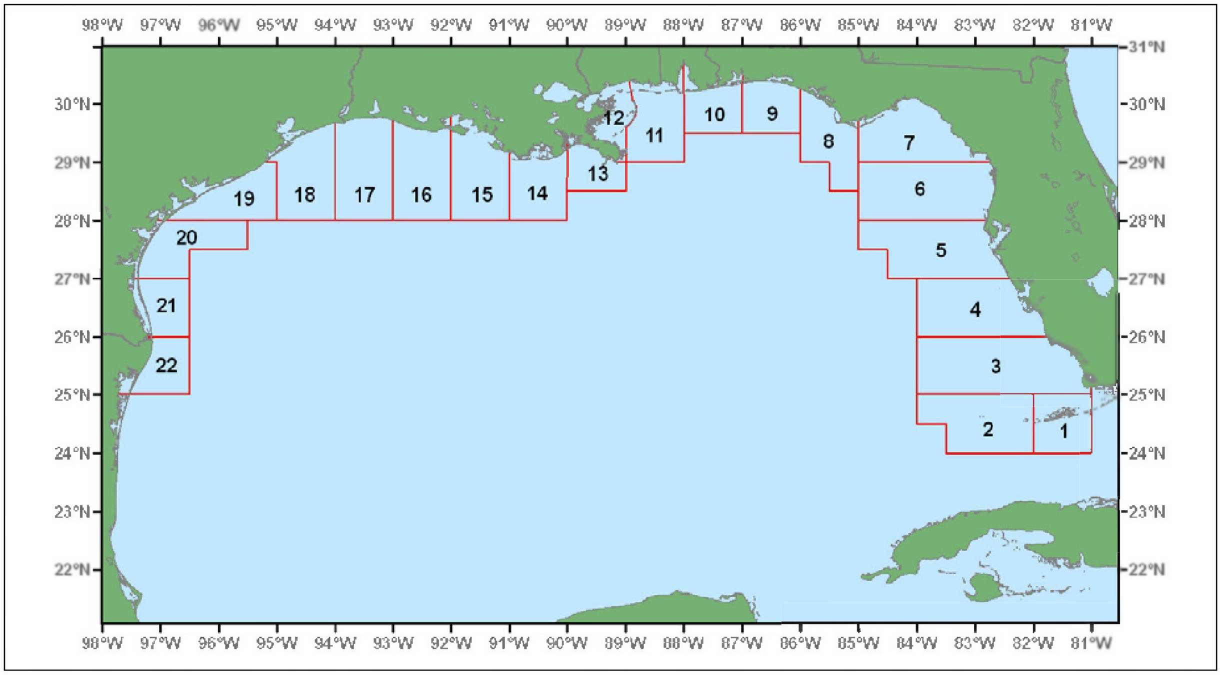


Figure A-14. Shrimp statistical zones for SEAMAP Shrimp/Groundfish Trawls. Source : Rester and Noble (2009).

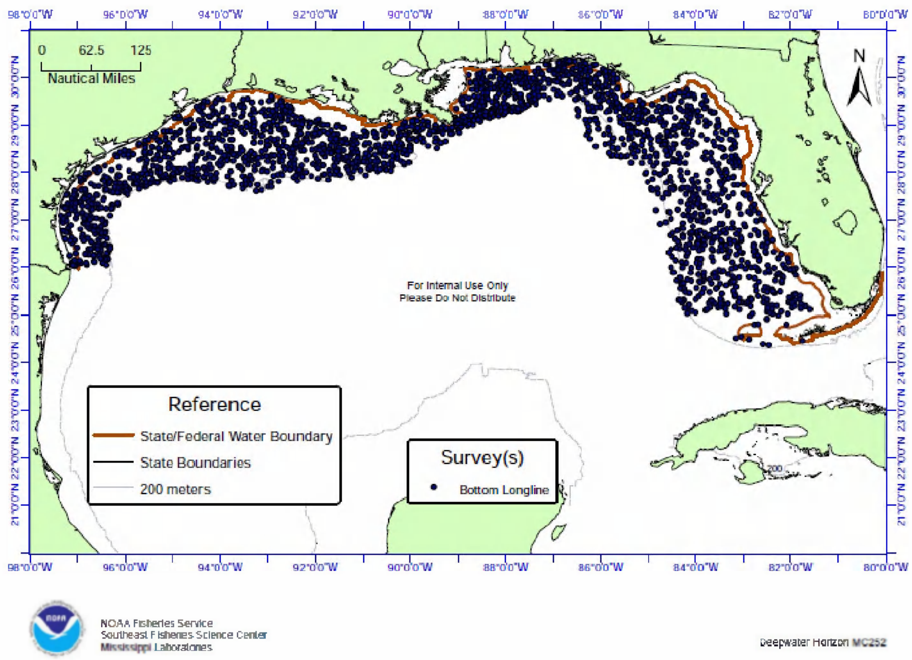


Figure A-15. Locations of NMFS Bottom Longline effort from 1995-2009.

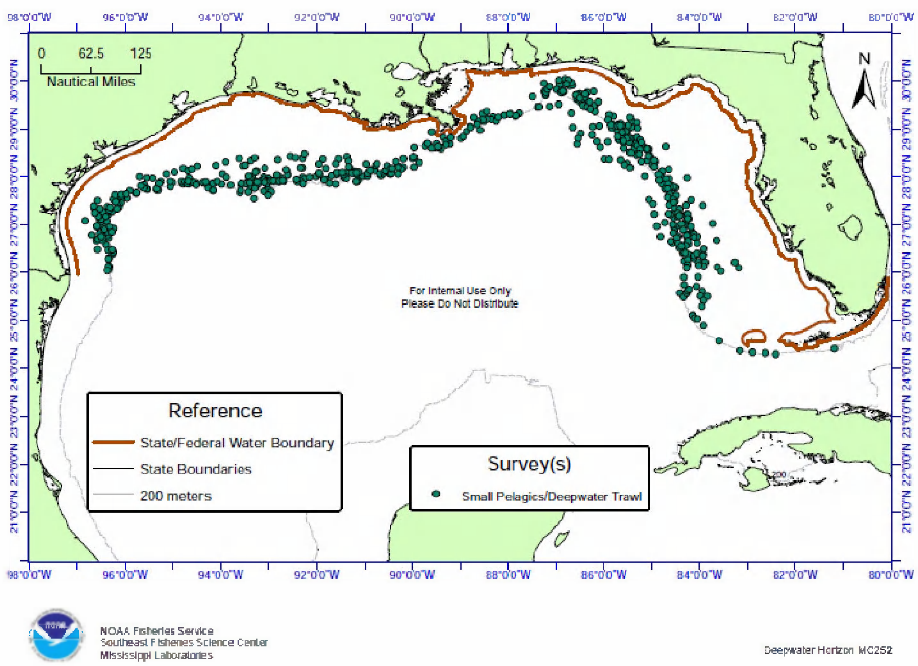


Figure A-16. Locations of NMFS Small Pelagics/Deep Trawl effort from 2002-2007.

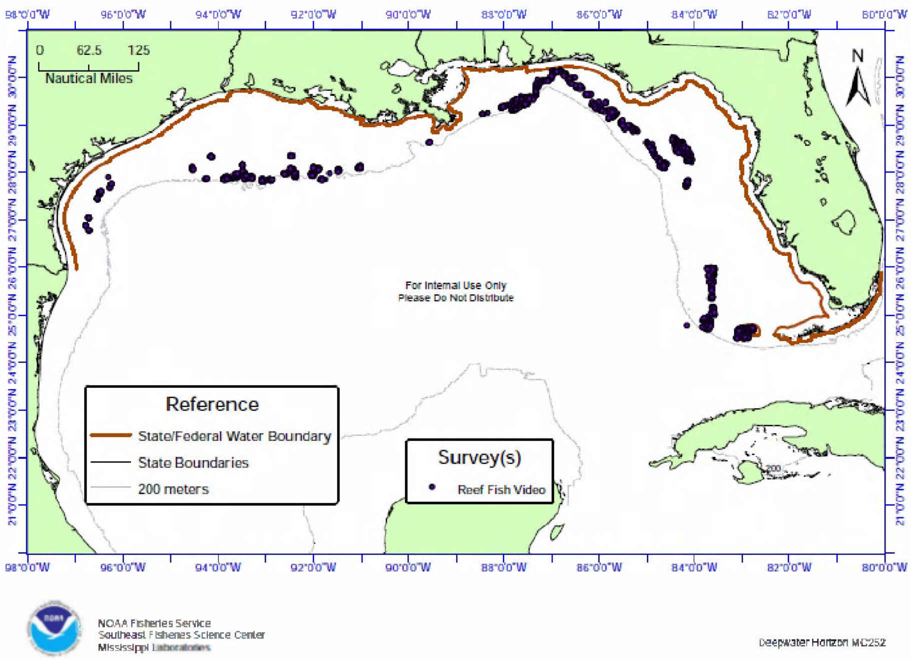


Figure A-17. Locations of NMFS Reef Fish Video effort from 1993-2009.

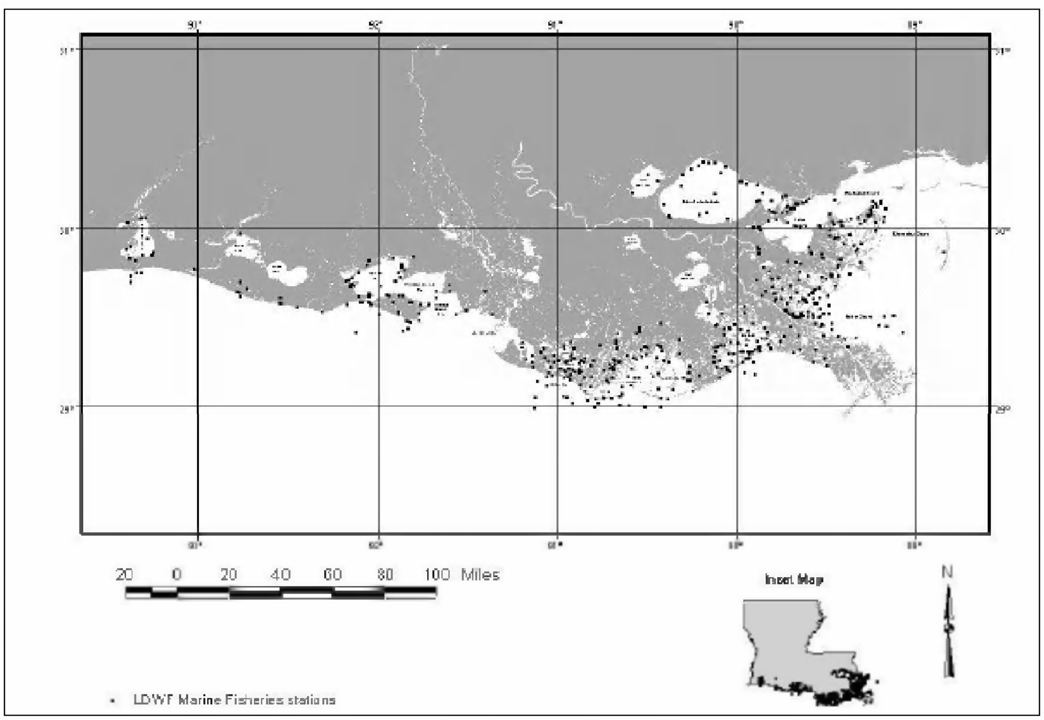


Figure A-18. LDWF Marine Fisheries Station Locations (Source: Louisiana Department of Wildlife and Fisheries (LDFW), Office of Fisheries, Marine Fisheries Division: Database Description. Baton Rouge, LA: 30 June 2000).

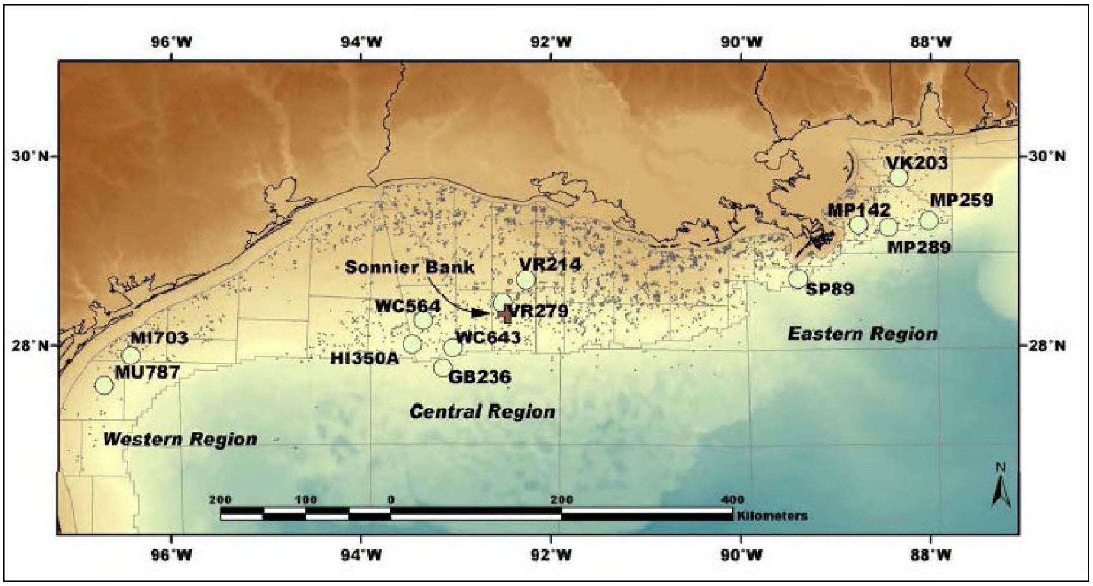
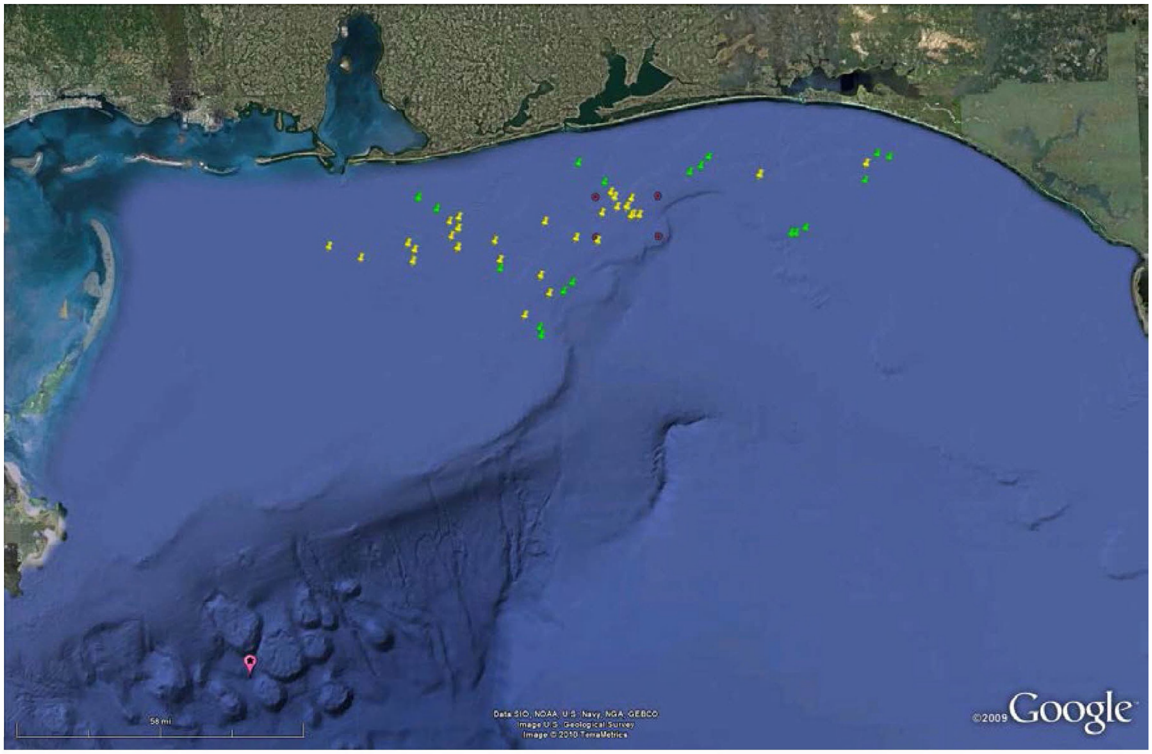


Figure A-19. Overview map of study platforms, regions and location of Sonnier Bank. Graded color background indicates depth and elevation (Source: Wilson et al.; 2006).

A



B.

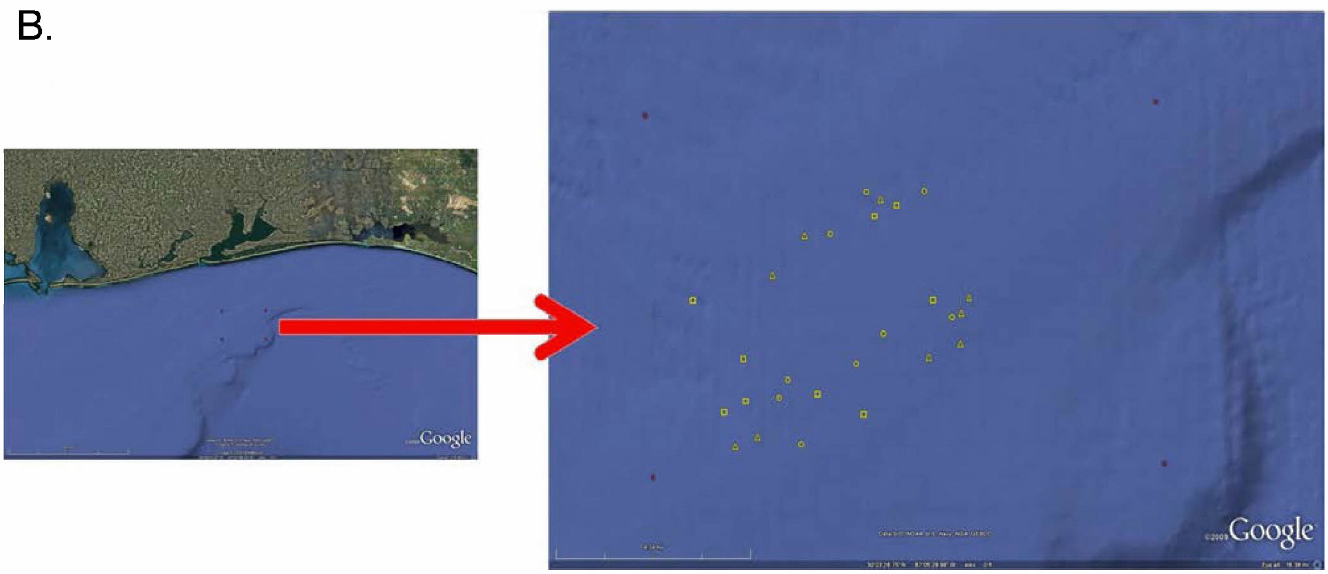


Figure A-20. Patterson Reef Sampling Figure: A. Natural (green symbols) and artificial (yellow symbols) reef sites sampled with ROV and hook-and-line sampling through 6-3-2010 to establish baseline data for potential oil impacts due to Deepwater Horizon (pink symbol with star) well blowout. Polygon denoted with red circles contains 27 additional (shown in B.) artificial reef sites that were sampled quarterly with ROV from fall 2004 until winter 2010.

A.3.2 Offshore Waters (>200 m deep)

Table A-3 provides potential data sources for deriving juvenile and adult fish and pelagic or demersal invertebrate baseline densities in offshore waters.

Table A-3. Available Biological Data Sources for Fish and Invertebrates in Offshore Waters (>200 m deep).

Source	Geographic Location	Gear	Sampling Period	Available Data[2]
NMFS surface long-line survey	Varied area coverage within Gulf and Atlantic (e.g. adaptive based upon temperature/current regimes) depths >183 m	5 nautical mile mainline fishing 200 hooks fishing >= 40 m	Varied periods	Since 2005 - Data are based on catch, may only be available as CPUE (# of fish per long-line set), does not depict biomass or depth habitat
NMFS bottom long-line survey	Gulf wide, 9-366 m, proportional allocation within statistical zones (since 2001) (Figure A-15)	1.0 nautical mile mainline fishing 100 hooks during a 1-hr set	Primarily July-September	Since 1995
NMFS Small Pelagics/Deep Trawl Survey	Gulf of Mexico extending from Brownsville, TX to Tampa, FL in 40-500 m depths (Figure A-16)	Deepwater bottom trawl (90 feet high opening)	October-November	2002-2004, 2006-present
NMFS SEFSC (marine mammal prey survey)	~ Middle of GOM on shelf to slope and into deeper water	Mid-water trawling	February/March 2010, November 2010	Purpose of these surveys to look for sperm whale food (i.e., squid and giant squid); most likely fish were counted in trawls

[2] Data Availability as of September 2010

Source	Geographic Location	Gear	Sampling Period	Available Data[2]
Gulf SERPANT – LSU (M. Benfield), funded by MMS and BP	Various deep sea oil platforms in the Northern GOM, including the DWH platform, meso- and bathypelagic zones (>200 m)	Horizontal ROV transects at discrete depths	2006 – Present	Video imaging of mostly small pelagic fish and invertebrates, biodiversity database, estimates of relative density
GCRL and FDNR deepsea (up to 900) trawls (Tolley 1990)	0-900 m	GCRL : macroepifaunal trawl (March 1977), FDNR: 12'x6' Tucker Trawl (September 1984); 41' semi-balloon Otter trawl (April 1987)	1980's	
2007 MMS Study of Shipwrecks in GOM (Church et al. 2007)	Mississippi Canyon and fan with several sites near DWHOS site (Figure A-21)	ROV transects; videos examined for biological data for fish and invertebrates, identification and biota counts; Chevron traps and small minnow traps with small (e.g., 0.250mm) mesh sampled small macrofauna (shrimps, isopods, etc.), fish & inverts at depth		
Lophelia Project Cruises	Northern Gulf of Mexico continental slope – natural and artificial hard bottom habitats (17 sites), 400-2000m (Figure A-22)	ROV video and mosaic imaging	August-September (previous cruises occurred in June and September)	Cruise 1 (2008) Cruise 2 (2009) Cruise 3 (2009) Presence/absence and species identification of fish and mobile invertebrates associated with hard bottom and *Lophelia* coral sites

Source	Geographic Location	Gear	Sampling Period	Available Data[2]
MMS Deep Gulf of Mexico Benthos (DGoMB) Study	Northern Gulf of Mexico (200m to 3750 m depths) (Figure A-23)	0.2m^2 box core, 40' otter trawl, and seafloor photography	Late 1990's – 2000's	1999-2001
FSUCML Felicia Coleman, C. Koenig	Madison Swanson, Steamboat Lumps, Florida Keys (Hawk's Cay, Burnt Point, Seven Mile Bridge)	ROV, submersible, hook and line, video, still images, dive surveys	2000-2002, 2004, 2005	Habitat characterization, fish assemblages
FSUCML Felicia Coleman, C. Koenig	Florida Middle Grounds	ROV and SCUBA dive surveys, belt transects	May 2003	Video and still photos from 12 sites to evaluate physical and biological habitat features.
FSUCML Felicia Coleman	Pulley's Ridge	Submersibles and ROV	2000, 2001	21 dives with video for fish identification, enumeration, and quantification by hour of video time.
FSUCML C. Koenig, F. Coleman	Madison Swanson and vicinity	fish traps, bandit, hook and line, ROV	12/2007-	Hook and line fishing and fish traps are set in the reserve. Bandit and hook and line fishing data are collected on commercial and charter trips around the reserve to document spillover. Released reef fish are tagged and some reef fish in the reserve are acoustically tagged and monitored. Some past ROV videos and photos from Madison Swanson and Steamboat Lumps are also available.

Source	Geographic Location	Gear	Sampling Period	Available Data[2]
FSUCML C. Koenig., F. Coleman	Florida Waters <150' deep	dive surveys, videos, some hook and line	06/1999-	Underwater surveys, video, catch and release, and goliath grouper tagging. Work is continuing on goliath grouper spawning and reproduction.
FSUCML C. Stallings	south of Dog Island Reef	Fish dive surveys at 4 sites 10-15 m deep.	Seasonally 04/2009-	Temporal dynamics of reef fish communities on octocoral-sponge reefs. Population abundances of all fishes, including sizes of economically-important species, estimated at each site.
FSUCML C. Stallings, C. Koenig	10-20m deep, off Dog Island to St. Marks	Dive surveys, videos, and photos of hardbottom and artificial reef flora and fauna.	04/2009-	Video, photographs, dive surveys, and sidescan data have been collected for hardbottom and artificial reef sites.

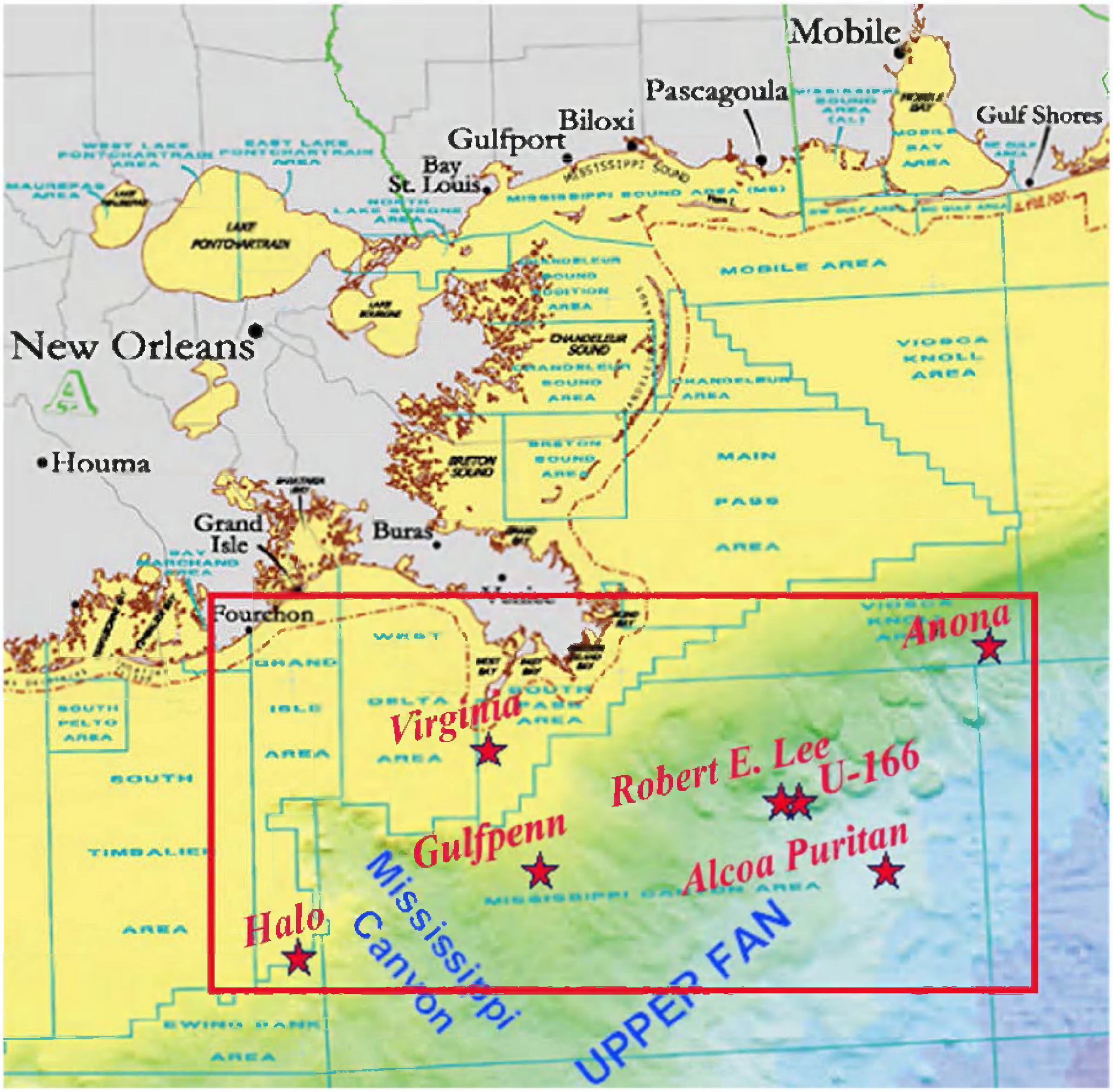


Figure A-21. Project area for 2007 MMS study of shipwrecks in Gulf of Mexico (Source: Church et al. 2007).

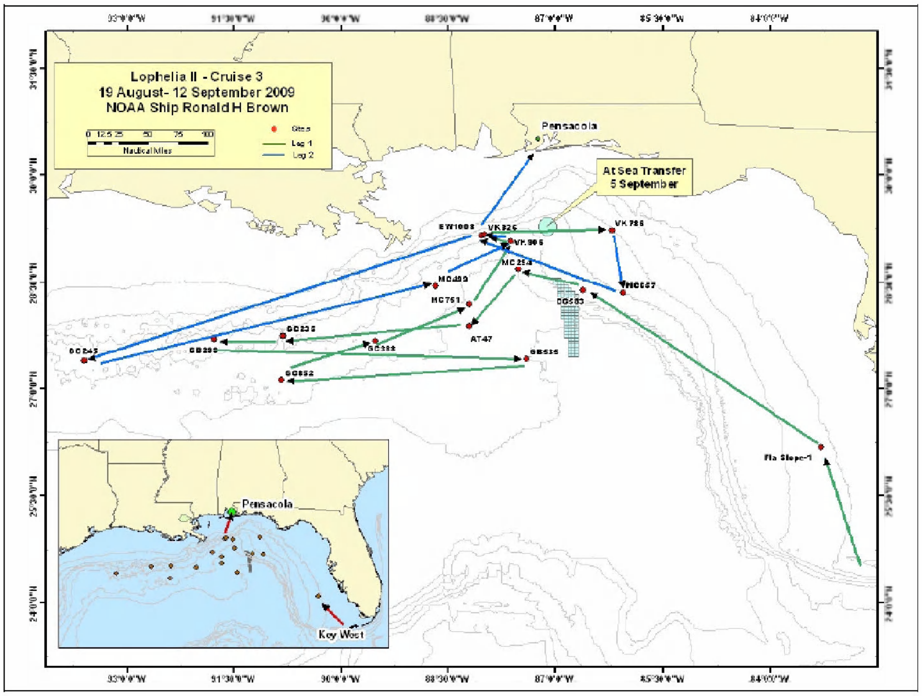


Figure A-22. Locations sampled during the Lophelia II Project– Cruise 3 (2009). Many of these sites were also visited during Cruise 1 (2008) and Cruise 2 (2009).

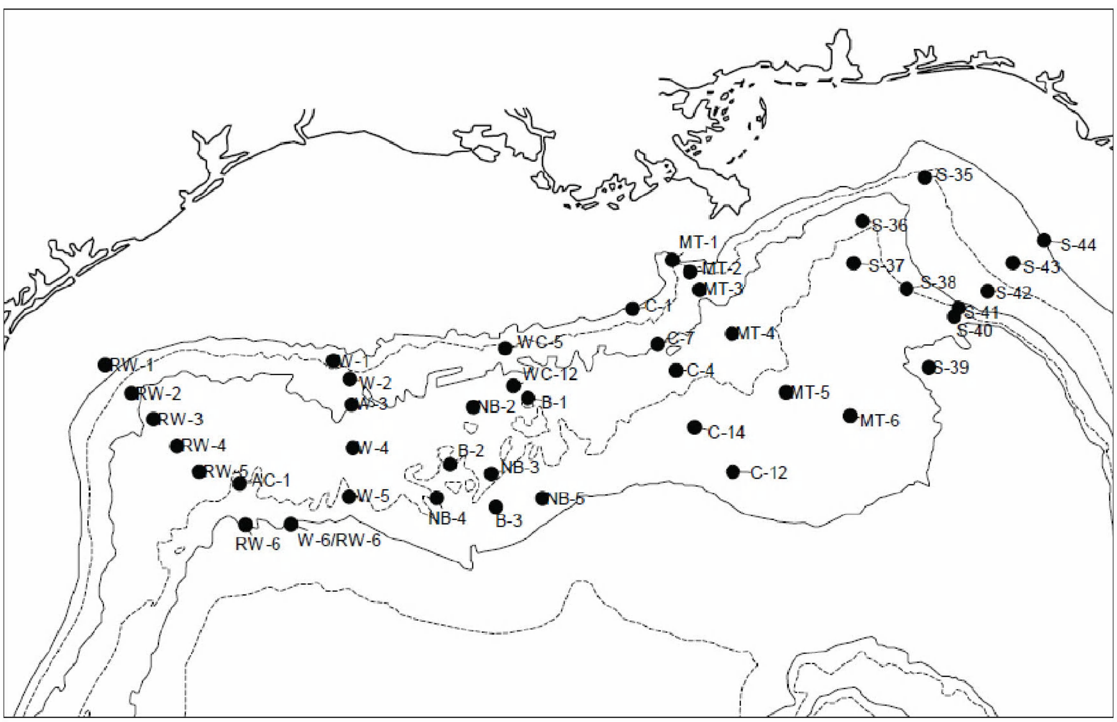


Figure A-23. MMS Deep Gulf of Mexico Benthos (DGoMB) stations in the Northern Gulf of Mexico. Source : Powell et al. 2003.

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Technical Reports for Deepwater Horizon Water Column Injury Assessment

WC_TR.10: Evaluation of Baseline Densities for Calculating Direct Injuries of Aquatic Biota During the Deepwater Horizon Oil Spill

Appendix B. Review of Catchability

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B.1 Definition of Catchability

Length distributions and numbers of individuals caught in nets are often underestimated because depending on the mesh size, large individuals may avoid the net or small individuals may be extruded through the mesh. These biases are often corrected by determining the ratio between catch in a standard net compared to a smaller mesh net assumed to capture all individuals (Somerton and Kobayashi 1989).

Catchability, the proportion of a stock captured by a standardized unit of effort, is determined through two main components, availability and vulnerability (Edwards 1968). A species is available to a gear if there is overlap between its location and the spatiotemporal location of the gear. Availability is comprised of three factors, vertical availability, horizontal availability and temporal availability. Vertical availability is determined by the gear's vertical location in the water column as compared to the species' vertical distribution in the water column. For example, a Gulf of Mexico (GOM) shrimp trawl might sample the bottom 1 m of the water column. Only species and fractions of stock that inhabit that portion of the water column would be vertically available to the gear. Horizontal availability can be affected by the distance from shore at which the gear is used and the distance from shore at which the stock exists. A stock is only available to a gear if there is overlap between these two locations. The third component of availability is temporal availability. A stock is only available to a gear if it exists in the same vertical/horizontal location at the time of sampling. Temporal issues affecting availability include migratory behavior, such as for seasonal anadromous fish and highly migratory species.

A species is vulnerable to a gear if it cannot avoid the gear, either through directed movement or extrusion, when it is fully available to that gear. There are two components of vulnerability, including behavioral avoidance and size selectivity. Behavioral avoidance is the directed avoidance of a sampling gear by an individual organism primarily through swimming and, in the case of benthos, burying. Behavioral avoidance is assumed to inversely scale with age, as older larger fish are presumably more capable of avoiding a net through directed swimming. Species that school in particularly large schools (e.g., Gulf menhaden) may also exhibit vulnerability characteristics. This is because schools tend to be sporadic or not uniformly distributed at a given place and time, two variables very specific to density. The second component of vulnerability is size selectivity of the gear. Unlike behavioral avoidance, size selectivity is assumed to directly scale with size/age until the individual is completely recruited to the gear type, thus reflecting size-selective vulnerability to the gear. This can be an issue when quantifying ichthyoplankton abundances, as some larvae may not be large enough to be caught in certain mesh sizes (i.e., they fall out through the mesh), resulting in lower catch per unit effort (CPUE) than the true abundances. Since larger larvae might behaviorally avoid the net, ichthyoplankton sampling often capture a specific size range of organisms and miss those individuals in the smaller and larger ends of the spectrum.

Generally, when these factors are taken into consideration for catchability (q), the true density of an organism can be calculated as follows:

$$True\ Density = \frac{CPUE}{q}$$

Edwards (1968) estimated coefficients for availability (vertical and horizontal availability of individuals to the net), vulnerability (behavioral avoidance and extrusion), and temporal (seasonal) availability separately.

$$Availability\ x\ Vulnerability\ x\ Seasonality = Catchability$$

Edwards (1968) then multiplied these to estimate overall catchability. Availability was estimated using known biological data on vertical distributions obtained from television and echo sounding records performed by the bureau biologists at Boothbay Harbor Laboratory. Vulnerability was estimated from "observations from research submarines, underwater television observations of fish and their reactions to trawls and the components of trawls, studies of echo sounder records, comparative gear studies (Yankee trawl and Soviet 27.1 Herring Trawl both with 40 ft spread) and other data on behavior and distribution". In his paper, Edwards (1968) describes specific examples of how some species catchabilities were estimated, but does not cover all of the methodology. Survey areas used for this research were in the northwest Atlantic, including the Gulf of Maine, Georges Bank, Browns Bank, and Southern New England. Seasonal availability was based on known biological reports, some of which were subjective according to Edwards (1968).

B.2 Literature Review of Catchability and Approaches

B.2.1 Plankton Gears

There are two main factors which might cause catchability (q) to be less than 100% ($q < 1$) in plankton sampling gears: extrusion through the net and behavior.

B.2.1.1 Extrusion

Extrusion is the passing of organisms through the mesh of the net; thus, although they were present in the survey area and were momentarily captured by the net, they are not retained in the sample. Extrusion is expected to be more prominent for smaller organisms (depending on species or age) than for larger ones. Several studies with similar gear and sampling protocols to the SEAMAP Plankton Surveys have examined the performance of various mesh sizes in retaining different sizes and species of larval fish and invertebrate zooplankton. Somarakis et al. (1998) compared the catches of larvae between bongo nets with 0.335 mm mesh (i.e., NMFS SEAMAP bongo size) to 0.250 mm mesh and concluded that, at a low constant towing speed (1.5-2 knots), catches were the same with even very small (2-3 mm) clupeid larvae not being extruded (based on an extrusion catchability component equal to 1). Similarly, Colton et al. (1980) compared the catches from 0.253 mm and 0.333 mm mesh nets, and found that, even at some very fast tow speeds (up to 3.5 knots); the catches were not different based on length. Thus, they proposed an extrusion catchability equal to 1. Hernandez et al. (2011) analyzed the Dauphin Island Sea Lab (DISL) ichthyoplankton catches for 0.202 mm versus 0.333 mm mesh. They found no significant difference in larval fish CPUE for most of the taxa analyzed (including total, Leptocephali and Syngnathidae, other fish, Serranidae, damaged specimens, and unidentified species).

Johnson and Morse (1994) evaluated the influence of extrusion by comparing catch ratios of select fish between 0.333 and 0.505mm mesh bongo nets in the Northwest Atlantic. While extrusion models were constructed for eight species/genera, the authors could not construct models for other taxa due to low catches. Laird-Gompertz models calculating 0.333:0.505 catch ratios by larval standard length revealed extrusion occurring for selected species up to 8 mm in length (depending on the species).

In contrast, Comyns (1977) noted that a tucker trawl with a 0.202 mm mesh captured 5.7 to 8.1 times as many small larvae (1.5-1.9 mm, which is a little smaller than those in Somarakis et al.

[1998] or Colton et al. [1980]) as with a 0.333 mm mesh, when towed at 2 knots. However, Comyns (1977) did not specifically discuss differences in the catch of larger larvae between the two nets, and indicated catchability was relevant for only this smallest size class. When Colton et al. (1980) analyzed the differences in retention of smaller zooplankton between the two nets; they found that there was a significant difference in the average abundance ratio between the 0.253 mm mesh and 0.333 mm mesh at different speeds. Most of the zooplankton taxa considered were between 0.5 mm and 2 mm long. Since zooplankton do not have yolk sacs, they are probably more likely than tiny ichthyoplankton to fit through the net openings. In summary, for the 0.333 mm mesh bongo net in the SEAMAP Plankton Survey data, extrusion likely only affects larvae less than 2 mm in length.

Extrusion for the relatively large SEAMAP neuston 1 mm mesh net is not well studied. Leslie and Timmins (1989) found that when towing a 1 mm mesh net inside of a 0.14 mm mesh outer net (at high tow speeds greater than 3.3 knots), the 1 mm mesh retained 74% of the larvae (with q due to extrusion = 0.74). The maximum volume of water actually filtered in 10 minutes was 30 m^3, which is on average one-half the water column presented to the sampler. If the reduced water filtered reflected the inner net clogging and thus missed larvae due to their avoidance, perhaps they were instead caught by the outer net, thus increasing the overall catchability.

Given that extrusion is more pronounced for smaller larval size classes, analyses that depend specifically on bongo catch length distributions of some species of smaller larvae may need to consider length-specific V_E based on evidence from the literature (Johnson and Morse 1994). For example, Hernandez et al. (2011) presented data on the proportion of catch at length of larval Sciaenidae for 0.333 mm vs. 0.202 mm mesh, and for the 1 mm size class the ratio of abundance was approximately 60/80 (or 0.75), thus $V_{E,1mm}$ = 0.75.

B.2.1.2 Behavior

While extrusion from the SEAMAP bongo or neuston gears at typical tow speeds might not affect overall density calculations, decreased catchability of plankton in these gears due to avoidance (either actively or otherwise) is likely.

Morse et al. (1989) noted that when the whole water column is fished with a bongo net, catches at the same site during the night are typically higher than those during the day. Since larvae cannot vertically move out of the fishing area of the gear and are likely unable to migrate away from the sample site, it seems that some larvae avoid entering the net, perhaps cued by visual stimuli. Morse et al. (1989) analyzed catches in relation to time of day and fit multiple linear models by species throughout the day to the peak catches. On average, they found that night to day catch ratios were highly variable across species, with some ratios much greater than 1. For example, the ratio for *Brevoortia tyrannus* was 5.23 to 1; however, the raw average across all species was 1.62 to 1. A night to day ratio of 1.62 implies that behavioral catchability is equal to 0.62.

Similar to Morse (1989), Somarakis et al. (1998) found catch numbers in the night greater than those during the day; however, they noted that this trend did not appear until larvae were capable of notochord flexion (e.g., for the European anchovy in the study, flexion started at ~ 6.5 mm). For larvae less than 6.5 mm in length, the night to day catch ratio was approximately 1 to 1, while for larger larvae the night to day catch ratio was 1.5 to 3.75. The night to day catch ratio over all larval lengths was 1 to 1.12.

Simplified night to day catch analyses were performed for the SEAMAP ichthyoplankton data based on those performed by Morse (1989) and Somarakis et al. (1998). Bongo tows taken in depths less than 200 m were used over all years in the entire Gulf of Mexico (north of 25°N, west of 81.5°W). The SEAMAP protocols dictate that the bongo gear is towed from as close to the bottom as possible up to the surface if the station is at 200 m or less, so the whole water column is sampled. However, the bongo is only fished in the surface 200 m at deeper stations; thus allowing larvae to vertically migrate below the sampling depth of the gear during either the day or the night. Night and day catch per unit effort (CPUE) were compared, excluding all twilight samples taken within 1 hour of sunrise or sunset. Like the other studies, day and night catches differed among species. Some night to day ratios were very large (e.g., 14.7 to 1 for Elopiformes (tarpons) and 11.23 to 1 for *Scombrolabrax heterolepis* (longfin escolar)), while the night to day catch ratios for other species was equal to or less than 1 (e.g., 0.53 to 1 for bluefin tuna, *Caranx* species (jacks), and most drums). The overall night to day catch ratios were 1.66 to 1 (q = 0.6), which nearly equals the ratio reported in Morse et al. (1989) and is slightly higher than the ratio reported in Somarakis et al. (1998). The analyses were repeated with larvae grouped by family (where possible) or order. The higher level results for were similar to those found at the analysis taxon level, with Elopiformes (tarpons) having the highest night to day catch ratio of 14.7 to 1. Other noteworthy ratios were Scombrolabracidae at 11.24 to 1, Anguillidae at 9.63 to 1, and Sciaenidae at 1.58 to 1. Thus, avoidance appears to be a catchability issue for some ichthyoplankton taxa in our dataset.

B.2.1 Bottom Trawl Gears

Although quantifying the relative difference between gear types for standardization is more common than estimating absolute efficiency, there are a few different methods of estimating catchability that have been used with bottom trawl gear. It is important to note that catchability can involve multiple factors. Vulnerability applies when fish are present at the time and place of sampling, but are not caught; while availability accounts for the vertical distribution of fish. For example, herring are typically caught relatively far above the seafloor; therefore, bottom trawl sampling may not co-occur with the temporal and spatial distribution of the stock. Where possible for this analysis, stock-specific areal and seasonal catchability were excluded and only vulnerability x availability were considered.

B.2.1.1 Method 1: Stock Assessment vs. Survey

Brodziak et al. (2007) and Harley and Myers (2001) applied a Bayesian framework to examine the relationship between survey catch (i.e., observed biomass) and stock assessed biomass (i.e., true biomass). This relationship estimates q, which can be further modeled as length-specific. The stock assessed biomass can be estimated from catch-at-age type models, such as age structured Virtual Population Analysis (VPA), which may combine survey catch data with fishery information such as catch and age-specific mortality, but which do not explicitly estimate q. Harley et al. (2001) provides a meta-analysis using this approach.

The relationship between survey catch and stock assessed biomass was estimated using Gulf menhaden in the GOM datasets because the SEDAR 27 provides stock numbers at age. Raw area fished abundance of Gulf menhaden was calculated from the SEAMAP Shrimp/Groundfish Survey data for 1985 through 2009 by assuming that the wingspread of the net was 30 feet, by using the actual distance towed, and by expanding the observed number per area to the entire Gulf of Mexico Exclusive Economic Zone. This "area fished" population estimate was compared to the stock assessment results in Figure B-1.

In the case of Gulf menhaden, the relationship between catch in the SEAMAP Shrimp/Groundfish Survey and assessed stock size is not very strong. The slope of the relationship (q) over all years is 0.1141. The median calculated q by year is 0.12, whereas the mean is 0.22. However, the mean is close to Edwards (1968) estimate of q = 0.27 for alewife in the northwest Atlantic.

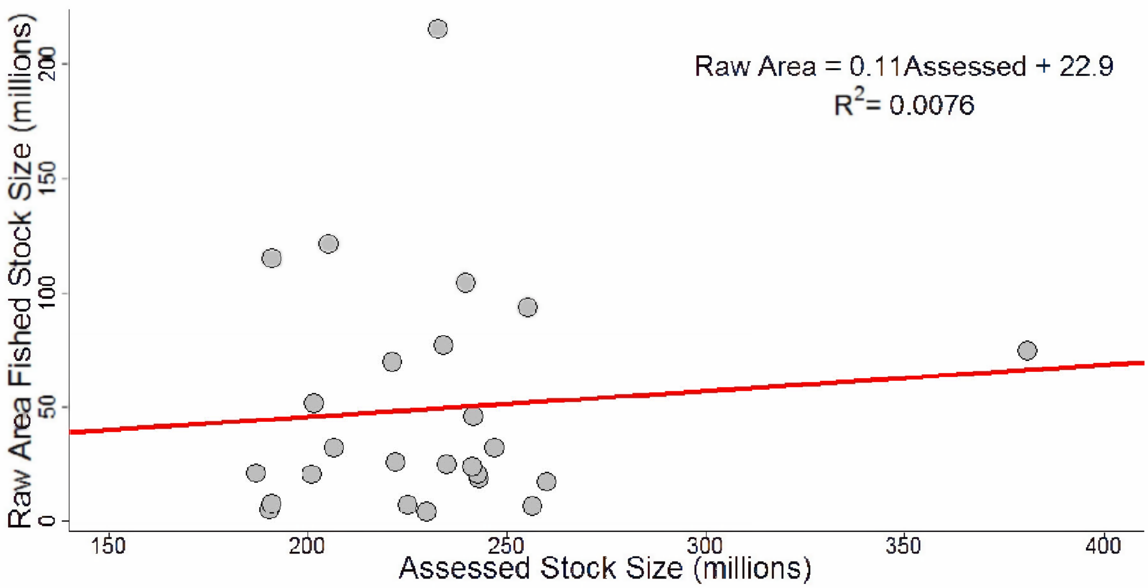

Figure B-1. Comparison of "area fished" population estimate for Gulf menhaden with stock assessment results from SEDAR 27.

B.2.1.2 Method 2: Mark-recapture Population Size Estimates vs. Survey

Like the stock assessment comparison, mark-recapture studies estimate a closed/semi-closed population size and then compare the estimated population size with the raw survey gear area-fished estimates to derive q. Studies that have examined this approach include Loesch et al. (1976) and Kjelson and Johnson (1978).

B.2.1.3 Method 3: Compare a Bottom Trawl to a More Effective Gear

Edwards (1968) compared a bottom trawl with a more effective gear, combined with other qualitative observations, to derive most of his q estimates. These q estimates have been cited often over the years, and were generally supported by the results of the analyses conducted by Harley et al. (2001). Specifically, Edwards (1968) compared catch rates between the Albatross IV Yankee-36 foot net and the larger head-rope height Soviet trawl used by the foreign fleet, which was much more effective at catching semi-demersal species such as mackerel, herring, and whiting.

In a similar comparison, Somerton et al. (2007) used a specially modified bottom trawl with chain ground gear to capture fish that escaped under the footrope. This gear is comparable to the SEAMAP Shrimp/Groundfish Survey trawl net, which uses a separate net to capture escaping fish, such as flatfish. Once the number of fish that would have escaped capture was calculated, Somerton et al. (2007) estimated the catchability of the un-modified net for four species of flatfish, and provided length-specific catchabilities. These length-specific catchabilities might be useful for the smaller flounder species often caught in the SEAMAP Shrimp/Groundfish Survey trawl.

Biron et al. (2007) compared area-fished estimated abundance of snow crabs to the abundance observed using camera surveys. Similarly, Minello et al. (1991) compared catch by trawl to catch by drop-net, which is assumed to be 100% efficient. Also, for benthic invertebrates, Haywood et al. (2008) compared a shrimp trawl to a benthic sled and found that mud and gravel sediments, trawling effort and seabed current stress were significantly correlated with the nature of the seabed habitats.

B.2.1.4 Method 4: Direct Observation of Fish Behavior

Some studies have used divers or video monitoring of gear while fishing to observe the manner and frequency with which fish avoid the net. Albert et al. (2003) used video footage during trawl surveys for Greenland halibut to determine the number of halibut lost from the trawl but observed in the footage, and how catchability varied with length. Reid et al. (2007) placed cameras at the wings of the trawl nets to determine the herding of anglerfish (*Lophius* sp.) and develop gear efficiency estimates. They found that fish in front of the net were caught, but those between the net and the wings were not caught effectively, indicating that anglerfish may not herd as previously expected and thus proportions of the population may not be captured when sampling.

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WC_TR.10: Evaluation of Baseline Densities for Calculating Direct Injuries of Aquatic Biota During the Deepwater Horizon Oil Spill

Appendix C. Fraction by Life Stage and Age Class for Fish Caught in Ichthyoplankton Samples

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C.1 SEAMAP Ichthyoplankton Survey

Fish captured in the SEAMAP ichthyoplankton survey were apportioned to fractions considered larvae versus those considered juveniles based on length, as described in Section 7.1.1.4 in the main report. Table C-1 tabulates the fraction considered larvae.

Table C-1. Percent of each analysis taxa caught in the SEAMAP Ichthyoplankton survey bongo samples considered to be true larvae. If the percentage is less than 100%, the other fraction was considered to be juveniles.

Taxa	Percent Larvae - Spring	Percent Larvae - Summer
ACANTHOCYBIUM_SOLANDRI	100	100
ACANTHURIDAE	100	100
ACHIRIDAE	100	100
ACROPOMATIDAE	99.33	98.74
ALBULIDAE	100	100
ALEPISAURUS	100	100
ALUTERUS	100	100
ANGUILLIFORMES	98.46	98.43
ANTHIINAE	100	100
ANTIGONIA	100	100
APOGONIDAE	100	100
ARGENTINIDAE	100	100
ARGENTINOIDEI	100	100
ARIOMMA	100	100
ASTRONESTHINAE	86.36	80
ATHERINIFORMES	100	85.71
AULOPUS	100	100
AUXIS	99.87	100
BAIRDIELLA_CHRYSOURA	100	100
BALISTES	100	100
BALISTES_CAPRISCUS	100	100
BALISTIDAE	100	100
BATHYLAGIDAE	100	100
BELONIDAE	100	100
BENTHOSEMA_SUBORBITALE	98.40	100
BERYCIFORMES	100	100

Taxa	Percent Larvae - Spring	Percent Larvae - Summer
BLENNIIDAE	100	100
BOLINICHTHYS	85.71	75
BOTHIDAE	99.51	100
BOTHUS	100	99.77
BRAMIDAE	100	100
BREGMACEROS	99.04	99.39
BREVOORTIA	100	100
CALLIONYMIDAE	100	100
CANTHERHINES	100	100
CANTHIDERMIS_MACULATA	100	100
CANTHIDERMIS_SUFFLAMEN	100	100
CARANGIDAE	100	99.82
CARANX	100	99.85
CARAPIDAE	70.49	88.69
CENTROBRANCHUS_NIGROOCELLATUS	97.81	100
CERATIOIDEA	100	99.81
CERATOSCOPELUS	98.64	99.59
CHAETODIPTERUS_FABER	100	100
CHAETODONTIDAE	100	100
CHAULIODONTINAE	86.02	86.67
CHIASMODONTIDAE	100	100
CHLOROPHTHALMIDAE	94.74	100
CHLOROSCOMBRUS_CHRYSURUS	99.75	99.90
CIRRHITIDAE	100	100
CITHARICHTHYS	100	99.63
CLUPEIDAE	98.88	99.73
CLUPEIFORMES	100	100
CONGRIDAE	63.69	81.89
CORYPHAENA	100	98.28
CUBICEPS_PAUCIRADIATUS	99.85	100
CYCLOPSETTA	98.04	99.25
CYNOSCION	100	99.90
CYNOSCION_NEBULOSUS	100	100

Taxa	Percent Larvae - Spring	Percent Larvae - Summer
DACTYLOPTERUS_VOLITANS	100	100
DECAPTERUS_PUNCTATUS	99.37	99.82
DIAPHUS	98.94	100
DIODONTIDAE	100	100
DIOGENICHTHYS_ATLANTICUS	99.87	100
DIPLOSPINUS_MULTISTRIATUS	98.05	100
ECHENEIDAE	100	100
ELAGATIS_BIPINNULATA	99.63	100
ELOPIFORMES	0	94.12
ENGRAULIDAE	99.01	99.68
ENGYOPHRYS_SENTA	100	100
EPIGONIDAE	100	100
EPINEPHELINI	100	100
EPINNULA_MAGISTRALIS	100	100
ETROPUS	100	100
ETRUMEUS_TERES	100	100
EUTHYNNUS_ALLETTERATUS	99.83	99.89
EVERMANNELLIDAE	100	100
EXOCOETOIDEA	97.47	95.74
FISH_EGGS	#N/A	#N/A
FISTULARIIDAE	80	87.50
GADIFORMES	100	98.68
GEMPYLIDAE	100	100
GEMPYLUS_SERPENS	98.85	100
GERREIDAE	100	100
GOBIESOCIDAE	100	100
GOBIIDAE	100	100
GONICHTHYS_COCCO	100	100
GONOSTOMATIDAE	98.88	99.10
GRAMMISTINI	100	100
HAEMULIDAE	100	100
HARENGULA	100	99.88
HOLOCENTRIDAE	96.08	100

Taxa	Percent Larvae - Spring	Percent Larvae - Summer
HOWELLA	100	100
HYGOPHUM	100	100
IDIACANTHINAE	80	66.67
ISTIOPHORIDAE	100	100
KATSUWONUS_PELAMIS	99.80	100
KYPHOSUS	100	100
LABRIDAE	100	100
LAMPADENA	99.31	100
LAMPANYCTUS	97.55	98.09
LAMPRIDIFORMES	100	100
LARIMUS_FASCIATUS	100	100
LEIOSTOMUS_XANTHURUS	100	100
LEPIDOPHANES	33.33	66.67
LOBIANCHIA	100	100
LOBOTES_SURINAMENSIS	100	100
LOPHIIDAE	100	100
LUTJANIDAE	100	100
LUTJANUS	100	99.89
LUTJANUS_CAMPECHANUS	100	100
LUTJANUS_GRISEUS	100	100
LUVARUS_IMPERIALIS	100	100
MACRORAMPHOSUS_SCOLOPAX	100	100
MACROURIDAE	96.30	100
MALACANTHIDAE	100	100
MALACOSTEINAE	66.67	100
MELAMPHAIDAE	100	99.38
MELANOSTOMIINAE	93.60	97.22
MENTICIRRHUS	100	99.93
MICRODESMIDAE	94.89	98.49
MICROPOGONIAS_UNDULATUS	100	100
MIRAPINNIDAE	80	100
MONACANTHIDAE	100	99.60
MONOLENE	100	100

Taxa	Percent Larvae - Spring	Percent Larvae - Summer
MORIDAE	100	100
MORINGUIDAE	0	100
MUGIL	95.60	100
MULLIDAE	97.75	100
MURAENIDAE	16.67	6.25
MYCTOPHIDAE	98.57	100
MYCTOPHIFORMES	98.28	100
MYCTOPHUM	98.50	100
NEOEPINNULA_AMERICANA	100	100
NESIARCHUS_NASUTUS	100	100
NETTASTOMATIDAE	62.86	75
NOTOLYCHNUS_VALDIVIAE	99.51	100
NOTOSCOPELUS	98.95	100
NOTOSUDIDAE	100	100
OLIGOPLITES_SAURUS	100	100
OMOSUDIS_LOWII	100	100
OPHICHTHIDAE	60.40	62.33
OPHIDIIFORMES	96.22	99.53
OPISTHONEMA_OGLINUM	99.50	99.78
OPISTOGNATHIDAE	100	100
OSTRACIIDAE	100	100
PARALEPIDIDAE	96.82	97.64
PARALICHTHYIDAE	100	100
PARALICHTHYS	100	100
PAREQUES	100	100
PEPRILUS	100	100
PEPRILUS_BURTI	100	100
PEPRILUS_PARU	100	100
PERCIFORMES	100	100
PERCOPHIDAE	100	100
PERISTEDION	87.50	100
PHOSICHTHYIDAE	99.09	99.09
PHYCINAE	100	100

Taxa	Percent Larvae - Spring	Percent Larvae - Summer
PLEURONECTIFORMES	100	100
POECILOPSETTA	100	100
POLYMIXIA	87.50	100
POMACANTHIDAE	100	100
POMACENTRIDAE	100	100
POMATOMUS_SALTATRIX	100	100
PRIACANTHIDAE	100	100
PRISTIPOMOIDES	99.51	99.93
PROMETHICHTHYS_PROMETHEUS	100	100
PSENES	100	100
RACHYCENTRON_CANADUM	100	100
RHOMBOPLITES_AURORUBENS	100	99.71
SARDA_SARDA	100	100
SARDINELLA_AURITA	98.27	99.82
SCARIDAE	100	100
SCIAENIDAE	100	100
SCIAENOPS_OCELLATUS	100	100
SCOMBER_COLIAS	100	100
SCOMBEROMORUS	100	100
SCOMBEROMORUS_CAVALLA	100	99.84
SCOMBEROMORUS_MACULATUS	100	99.86
SCOMBRIDAE	100	100
SCOMBROLABRAX_HETEROLEPIS	100	100
SCOPELARCHIDAE	99.66	99.24
SCORPAENIDAE	99.44	100
SCORPAENIFORMES	100	100
SELAR_CRUMENOPHTHALMUS	100	99.80
SELENE	100	99.91
SERIOLA	96.88	100
SERRANIDAE	99.80	99.87
SERRANINAE	99.87	99.89
SPARIDAE	100	100
SPHYRAENA	100	99.82

Taxa	Percent Larvae - Spring	Percent Larvae - Summer
STEINDACHNERIA_ARGENTEA	50	100
STELLIFER_LANCEOLATUS	100	100
STEPHANOLEPIS	100	97.87
STEPHANOLEPIS_SETIFER	100	100
STERNOPTYCHIDAE	99.56	100
STOMIIFORMES	100	100
STOMIINAE	81.82	100
STROMATEIDAE	100	100
SYACIUM	100	99.96
SYMBOLOPHORUS_RUFINUS	100	100
SYMPHURUS	100	100
SYMPHYSANODON	100	100
SYNAPHOBRANCHIDAE	25	100
SYNGNATHIDAE	50	67.90
SYNODONTIDAE	98.43	99.51
TETRAGONURUS_ATLANTICUS	100	100
TETRAODONTIDAE	100	100
TETRAODONTIFORMES	100	100
THUNNUS	99.82	99.84
THUNNUS_THYNNUS	100	100
TRACHIPTERIDAE	87.50	100
TRACHURUS_LATHAMI	100	100
TRICHIURIDAE	98.08	100
TRICHIURUS_LEPTURUS	99.48	99.40
TRIGLIDAE	100	100
UNIDENTIFIED_FISH	98.75	100
URANOSCOPIDAE	100	100
XANTHICHTHYS_RINGENS	100	100
XIPHIAS_GLADIUS	100	100

C.2 NRDA Plankton Survey

Fish captured in the NRDA 1m^2-MOCNESS plankton survey from waters below 200 m were apportioned to fractions considered larvae versus those considered juveniles based on length, as described in Section 7.3.2 in the main report. Table C-2 tabulates the fraction considered larvae.

Table C-2. Percent of each fish analysis taxa caught in the NRDA Plankton Below 200m ($1m^2$ MOCNESS) samples considered to be true larvae. If the percentage is less than 100%, the other fraction was considered to be juveniles.

Analysis Taxa	Percent Larvae
Argyropelecus	100
Argyropelecus aculeatus	84.21
Argyropelecus affinis	100
Argyropelecus hemigymnus	95
Argyropelecus sladeni	100
Bathylaginae	87.5
Benthosema suborbitale	100
Ceratoscopelus warmingii	100
Chauliodus	33.33
Chauliodus danae	50
Cyclothone	40.63
Diaphus	100
Dolicholagus longirostris	93.75
Hygophum	97.64
Hygophum benoiti	88.89
Hygophum reinhardtii	92.31
Hygophum taaningi	100
Lampadena	93.75
Lampadena urophaos	100
Lampanyctus	57.5
Lampanyctus crocodilus	100
Lampanyctus nobilis	100
Myctophidae	100
Myctophum	96.77
Notolychnus	100
Notolychnus valdiviae	100
Osteichthyes	100

Analysis Taxa	Percent Larvae
Polyipnus	100
Sternoptyx	89.47
Sternoptyx diaphana	82.5
Sternoptyx pseudobscura	100
Stomiiformes	100
Valenciennellus tripunctulatus	72.97
Vinciguerria	100
Vinciguerria attenuata	100
Vinciguerria poweriae	100